3.0 REGIONAL GEOMORPHIC CHANGE

Nearshore sediment transport processes influence the evolution of shelf sedimentary environments to varying degrees depending on temporal and spatial response scales. Although micro-scale processes, such as turbulence and individual wave orbital velocities, determine the magnitude and direction of individual grain motion, variations in micro-scale processes are considered noise at regional-scale and only contribute to coastal response in an average sense. By definition, regional-scale geomorphic change refers to the evolution of depositional environments for large coastal stretches (10 km or greater) over extended time periods (decades or greater) (Larson and Kraus, 1995). An underlying premise for modeling long-term morphologic change is that a state of dynamic equilibrium is reached as a final stage of coastal evolution. However, the interaction between the scale of response and forces causing change may result in a net sediment deficit or surplus within a system, creating disequilibrium. This process of disequilibrium defines the evolution of coastal depositional systems.

Topographic and hydrographic surveys of coastal and nearshore morphology provide a direct source of data for quantifying regional geomorphology and change. Historically, hydrographic data have been collected in conjunction with regional shoreline position surveys by the U.S. Coast and Geodetic Survey (USC&GS); currently the Coast and Geodetic Survey of the National Ocean Service [NOS], National Oceanic and Atmospheric Administration [NOAA]). Comparison of digital bathymetric data for the same region but different time periods provides a method for calculating net sediment movements into (accretion) and out of (erosion) an area of study. Coastal scientists, engineers, and planners often use this information for estimating the magnitude and direction of sediment transport, monitoring engineering modifications to a beach, examining geomorphic variations in the coastal zone, establishing coastal erosion setback lines, and verifying shoreline change numerical models. The purpose of this portion of the study is to document patterns of geomorphic change throughout the sand resource areas and quantify the magnitude and direction of net sediment transport over the past 100 to 140 years. These data, in combination with wave and current measurements and model output, provide a temporally integrated approach for evaluating the potential physical impacts of offshore sand mining on sediment transport dynamics.

3.1 SHORELINE POSITION CHANGE

Creation of an accurate map is always a complex surveying and cartography task, but the influence of coastal processes, relative sea level, sediment source, climate, and human activities make shoreline mapping especially difficult. In this study, shoreline surveys are used to define landward boundaries for bathymetric surfaces and to document net shoreline movements between specified time periods. Consequently, net change results can be compared with wave model output and nearshore sediment transport simulations to evaluate cause and effect. Integration of results provides a direct method of documenting potential environmental impacts related to sand mining on the OCS.

3.1.1 Previous Studies

Beaches along the New Jersey coast are composed primarily of sand, silt, and gravel reworked from Cretaceous, Tertiary, and Quaternary Coastal Plain sediment (McMaster, 1954). Sediment is eroded from onshore Coastal Plain formations in the northern section of the coast or from submerged coastal plain sediment redistributed along the coast by waves and currents (Uptegrove et al., 1995). The northern limit of the study area is Manasquan Inlet, and the southern limit is Cape May. This length of shoreline encompasses an area referred to by Uptegrove et al. (1995) as the southern coast. Sand reworked from submerged Coastal Plain sediment mixes with southward-directed sediment originating from bluffs along the northern coast to form a series of barrier islands extending 5 to 18 miles (8 to 29 km) in length. Some of the greatest shoreline changes that occur along the outer coast are the result of inlet processes. Inlets interrupt longshore transport of beach sand, potentially restricting sediment transport at entrances. Furthermore, navigation structures used to control channel migration and shoaling may result in erosional and depositional “hot spots” along beaches adjacent to inlets. Seven inlets along the southern coast have at least one jetty or one shoreline armored with rock to control inlet channel migration (Uptegrove et al., 1995).

Historical shorelines for the entire coast of New Jersey were digitally mapped as part of the New Jersey Historical Map Series (Farrell and Leatherman, 1989). The primary benefit of these data was to document shoreline response since the mid-1800s to natural processes and engineering activities (e.g., beach nourishment, jetty and groin placement). Unfortunately, a regional quantitative assessment of shoreline change was never completed using the map series. Only a cursory analysis has been performed by the USACE using this data set to address site-specific project needs (e.g., USACE, 1996, 1997).

Short-term shoreline and beach volume changes have been monitored by the State since March 1986. The NJDEP’s Division of Engineering and Construction (DEC) contracted with the Stockton State College Coastal Research Center (CRC) to assist with planning and implementing the program. In Fall 1986, a survey team collected the first set of measurements at 83 beach profile stations along the Atlantic coast of New Jersey. Since this time, the CRC has collected annual beach profile measurements to document changes in beach sand volume and shoreline position. Uptegrove et al. (1995) provide details regarding these data for the period 1986 to 1992. Between Manasquan and Barnegat Inlets (Ocean County), a balance between beach erosion and accretion is illustrated; however, south of Barnegat Inlet to Little Egg Inlet, beach erosion has been chronic between 1986 and 1992 (Figure 3-1). In Atlantic and Cape May Counties, beach sand volume changes illustrate more variability depending on profile location relative to inlets and beach replenishment activities (Figure 3-2).

3.1.2 Shoreline Position Data Base

For the present study, six outer coast shoreline surveys were used to quantify historical shoreline change (Table 3-1). The first five surveys were conducted by the USC&GS in 1839/42, 1863/86, 1899, 1932/33, and 1950/51. The sixth survey was compiled by the NJGS in 1977 for the coast between Manasquan Inlet (north) and Hereford Inlet. The first three surveys were completed as field surveys using standard planetable techniques, whereas the final three shoreline surveys were interpreted from aerial photography. Data were compiled from historical maps and aerial photography by Farrell and Leatherman (1989). Digital data were provided for this study by the NJGS Geographic Information System Data and Resources group.

When determining shoreline position change, all data contain inherent errors associated with field and laboratory compilation procedures. These errors should be quantified to gauge the significance of measurements used for engineering/research applications and management decisions. Table 3-2 summarizes estimates of potential error for the shoreline data sets used in this study. Because these individual errors are considered to represent standard deviations, root-mean-square error estimates are calculated as a realistic assessment of combined potential error.

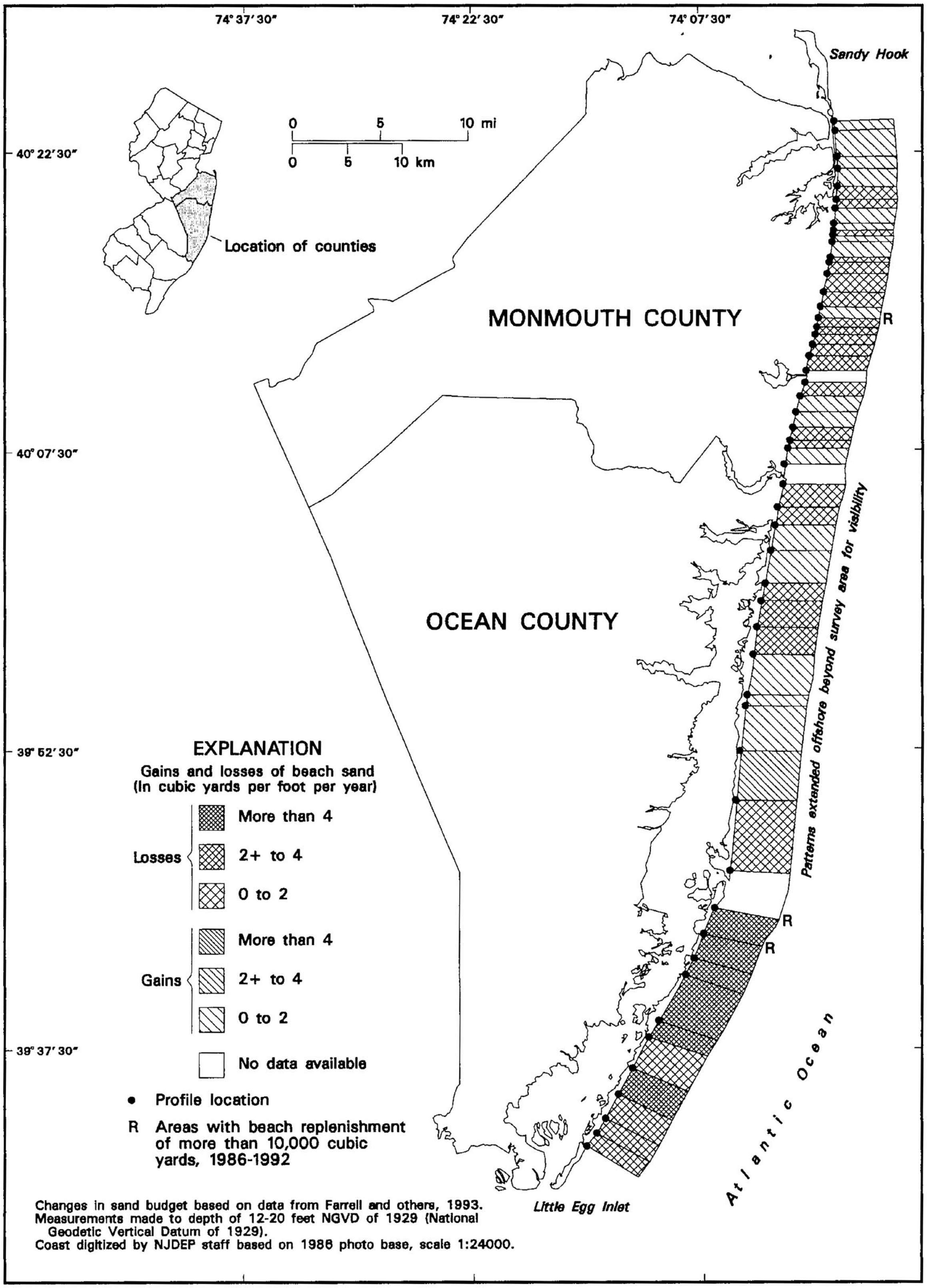

Figure 3-1. Changes in beach sediment volume and beach replenishment volume in Monmouth and Ocean Counties, New Jersey, 1986 to 1992 (from Uptegrove et al., 1995).

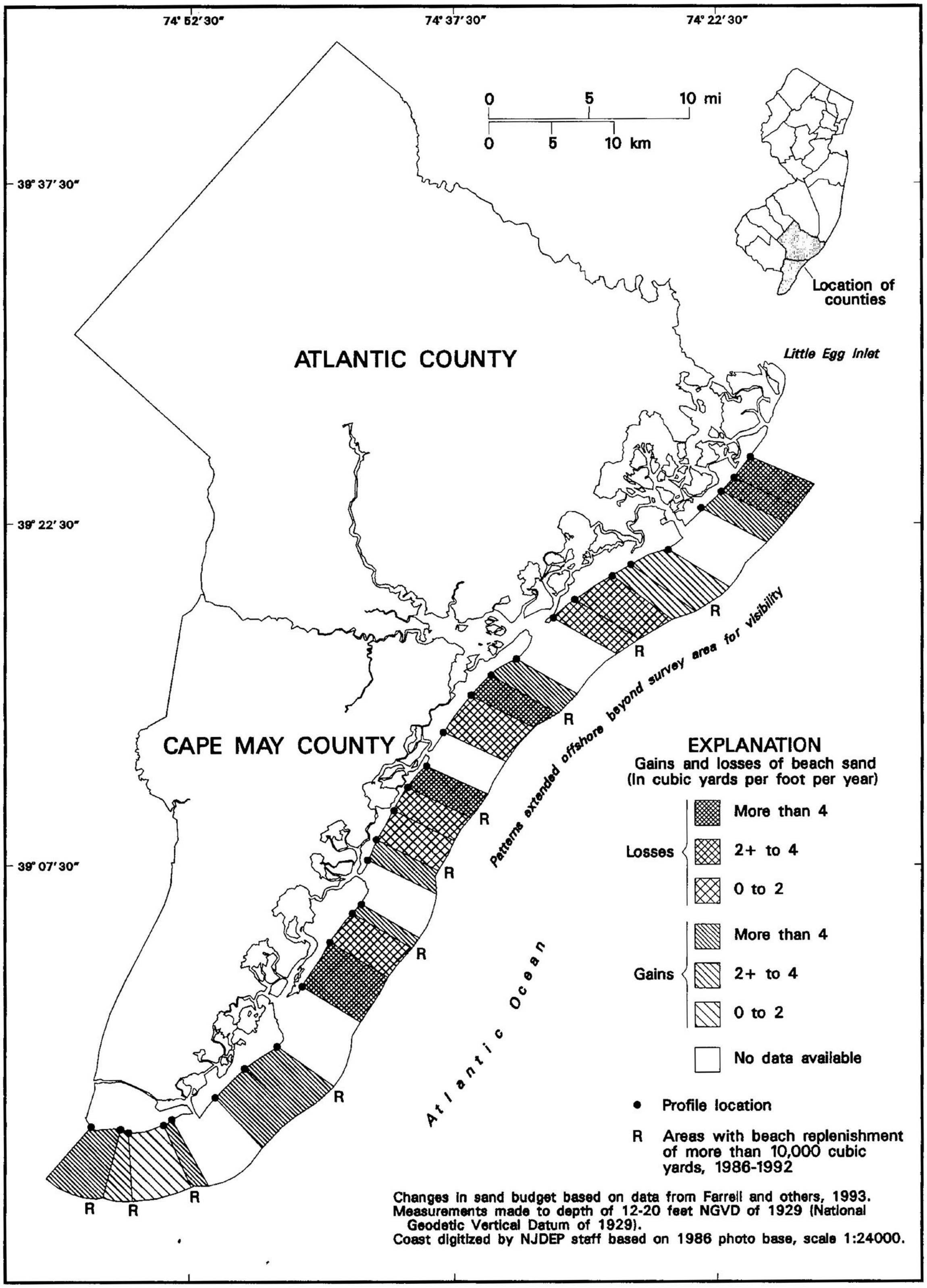

Figure 3-2. Changes in beach sediment volume and beach replenishment volume in Atlantic and Cape May Counties, New Jersey, 1986 to 1992 (from Uptegrove et al., 1995).

Table 3-1. Summary of shoreline source data characteristics for the New Jersey coast between Manasquan Inlet and Hereford Inlet.

Date	Data Source	Comments and Map Numbers
1839/42	U.S. Coast and Geodetic Survey (USC&GS) Topographic Maps 1:20,000 (T-116, T-119, T-120, T-121, T-142, T-143, T-146, T-147)	First regional shoreline survey throughout study area using standard planetable surveying techniques; 1839 - Manasquan Inlet south to central Long Beach Island (T-116, T-120, T-121); 1841 - central Long Beach Island south to Great Egg Inlet (T-119, T-142, T-143); 1842 - Great Egg Inlet south to Hereford Inlet (T-146, T-147).
1863/86	USC&GS Topographic Maps 1:10,000 (T-952) 1:20,000 (T-1084, T-1315a, T-1315b, T-1333, T-1371, T-1407, T-1532, T-1597, T-1744)	Second regional shoreline survey along the seaward coast of the study area using standard planetable surveying techniques; 1863/64 - Brigantine Inlet south to Longport (T-952); 1868 - Manasquan Inlet to northern Barnegat Bay (T-1084); 1871/75 - northern Barnegat Bay south to Little Egg Inlet (T-1315a, T-1315b, T-1333, T-1371, T-1407); 1881/86 - Longport south to Hereford Inlet (T-1532, T-1597, T-1744).
1899	USC&GS Topographic Maps 1:20,000	Third regional shoreline survey along the seaward coast of the New Jersey using standard planetable surveying techniques; Manasquan Inlet to Barnegat Inlet (T-2458, T-2459); Barnegat Inlet to Great Egg Inlet (T-2455, T-2456, T-2457); Great Egg Inlet to Hereford Inlet (T-2452, T-2453, T-2454).
April 1932/ May 1933	USC&GS Topographic Maps 1:10,000	First regional shoreline survey completed using aerial photography; Manasquan Inlet to Barnegat Inlet (T-5097, T-5284, T-5285, T-5286, T-5330); Barnegat Inlet to Great Egg Inlet (T-5099, T-5444, T-5445, T-5635, T-5637, T-5638); Great Egg Inlet to Hereford Inlet (T-5639, T-5642, T-5644, T-5645, T-5646, T-5647).
April 1950/ March 1951 and April 1943	USC&GS Topographic Maps 1:10,000 (T-9483N, T-9483S; T-9498N, T-9498S, T-9499N, T-9501S, T-9502N, T-9502S, T-9504S, T-9505N, T-9505S, T-9507N, T-9507S, T-9508N, T-9509N, T-9509S, T-9828N, T-9828S, T-9830N, T-9830S, T-9831N) 1:20,000 (T-8494)	All maps produced from interpreted aerial photography; April 1943 - Stone Harbor to Hereford Inlet (T-8494); April 1950 - Barnegat Inlet to Townsends Inlet (T-9501S, T-9502N/S, T-9504S, T-9505N/S, T-9507N/S, T-9508N, T-9509N/S); March 1951 - Manasquan Inlet to Barnegat Inlet, and Townsends Inlet to Stone Harbor (T-9483N/S, T-9498N/S, T-9499N, T-9828N/S, T-9830N/S, T-9831N).
1977	New Jersey Geological Survey (NJGS) 1:10,000	All maps produced from interpreted aerial photography; all shoreline information compiled and digitized by New Jersey Geological Survey personnel.

Table 3-2. Estimates of potential error associated with New Jersey shoreline position surveys.

Traditional Engineering Field Surveys (1839/42, 1863/86, and 1899)		
Location of rodded points	±1 m	
Location of plane table	±2 to 3 m	
Interpretation of high-water shoreline position at rodded points	±3 to 4 m	
Error due to sketching between rodded points	up to ±5 m	
Cartographic Errors (all maps for this study)	**Map Scale**	
	1:10,000	1:20,000
Inaccurate location of control points on map relative to true field location	up to ±3 m	up to ±6 m
Placement of shoreline on map	±5 m	±10 m
Line width for representing shoreline	±3 m	±6 m
Digitizer error	±1 m	±2 m
Operator error	±1 m	±2 m
Aerial Surveys (1932/33, 1950/51, 1977)	**Map Scale**	
	1:10,000	1:20,000
Delineating high-water shoreline position	±5 m	±10 m
Sources: Shalowitz, 1964; Ellis, 1978; Anders and Byrnes, 1991; Crowell et al., 1991.		

Positional errors for each shoreline can be calculated using the information in Table 3-2; however, change analysis requires comparing two shorelines from the same geographic area but different time periods. Table 3-3 is a summary of potential errors associated with change analyses computed for specific time intervals. As expected, maximum positional errors are aligned with the oldest shorelines (1839/42, 1863/86, and 1899) at smallest scale (1:20,000), but most change estimates for the study area document shoreline advance or retreat greater than these values.

Table 3-3. Maximum root-mean-square potential error for New Jersey shoreline change data.

	1863/86	1899	1932/33	1950/51	1977
1839/42	±21.5[1]	±21.5	±17.3	±17.3	±17.3
	(±0.6)[2]	(±0.4)	(±0.2)	(±0.2)	(±0.1)
1863/86		±21.5	±17.3	±17.3	±17.3
		(±0.9)	(±0.3)	(±0.2)	(±0.2)
1899			±17.3	±17.3	±17.3
			(±0.5)	(±0.3)	(±0.2)
1932/33				±11.8	±11.8
				(±0.7)	(±0.3)
1950/51					±11.8
					(±0.5)

[1] Magnitude of potential error associated with high-water shoreline position change (m); [2] Rate of potential error associated with high-water shoreline position change (m/yr).

3.1.3 Historical Change Trends

Regional change analyses completed for this study provide a without-project assessment of shoreline response for comparison with predicted changes in wave-energy focusing at the shoreline resulting from potential offshore sand dredging activities. It differs from previous qualitative analyses in that continuous measurements of shoreline change are provided at 50-m alongshore intervals for the period 1839/42 to 1977 (see Appendix A). As such, model results (wave and sediment transport) at discreet intervals along the coast can be compared with historical data to develop process/response relationships for evaluating potential impacts. The following discussion focuses on incremental changes in shoreline response (1839/42 to 1863/86, 1863/86 to 1899, 1899 to 1932/33, 1932/33 to 1950/51, 1950/51 to 1977) relative to net, long-term trends (1839/42 to 1977).

3.1.3.1 1839/42 to 1932

Shoreline response along the ocean beaches between Manasquan Inlet and Little Egg Inlet was significant for the period 1839/40 to 1872/74, illustrating large areas of shoreline recession north and south of Barnegat Inlet (up to 10 m/yr), as well as south of Manasquan Inlet (Figure 3-3). The average change rate for this area was about -2.3 m/yr ($\sigma = \pm 4.0$ m/yr); however, average change for areas of shoreline advance and retreat was 2.8 and -4.1 m/yr, respectively. Between 1872/74 and 1899, shoreline recession continued to dominate change trends for this section of coast, but the magnitude of change decreased along the shoreline 15 km north and south of Barnegat Inlet and increased substantially north of Little Egg Inlet. Average shoreline change was -1.8 m/yr ($\sigma = \pm 3.3$ m/yr), and average shoreline advance and retreat was 0.5 and -2.6 m/yr, respectively. Sediment transported alongshore by wave-induced currents created significant southward growth of Long Beach Island across Little Egg Inlet by 1872/74 (2.8 km or a southward migration rate of 85 m/yr). From 1872/74 to 1899, southward migration of Long Beach Island continued at a rate of about 46 m/yr, extending Long Beach Island about 1.2 km. However, shoreline recession of up to 15 m/yr ($\bar{x} = -6.5$ m/yr) resulted along the coast 10 km to the north (Figure 3-4). The same trend continued between 1899 and 1932; that is, greatest changes occurred adjacent to entrances. Except for the beach south of Barnegat Inlet and the beaches adjacent to Little Egg Inlet, shoreline changes were within ± 5 m/yr (Figure 3-5). Average change away from entrances was about -0.20 m/yr; average shoreline advance and retreat for the same area was 0.6 and -0.7 m/yr, respectively.

Shoreline changes along barrier island beaches south of Brigantine Inlet exhibited significantly greater variations than those to the north between 1841/42 and 1864/86. Greatest changes were again associated with inlets (up to 20 m/yr of recession and advance); however, net change between Brigantine and Hereford Inlets was about 1.1 m/yr (Figure 3-6) compared with -2.3 m/yr between Manasquan and Little Egg Inlets for the same time period (Figure 3-3).

The same level of variability in shoreline change rates was illustrated for the period 1864/86 to 1899. However, the average change rate for this section of coast was -0.5 m/yr, indicating that erosive processes and shoreline recession dominate (Figure 3-7). Although the average change rate is small, the variation between shoreline advance and retreat rates is large (18 to 20 m/yr), resulting in a standard deviation of 4.0. The average shoreline advance and retreat rates during this time were 2.6 and -2.8 m/yr, respectively. The most extreme changes again are associated with shorelines adjacent to inlets.

Between 1899 and 1932, overall patterns of shoreline change from Brigantine Inlet to Hereford Inlet remained influenced by inlet location and processes. Like earlier time periods, greatest rates of shoreline change (± 10 to 15 m/yr) were adjacent to entrances (Figure 3-8). Average shoreline change for the beaches south of Brigantine Inlet was 0.4 m/yr ($\sigma = \pm 3.7$ m/yr). The large standard deviation value indicates that peaks in shoreline advance and

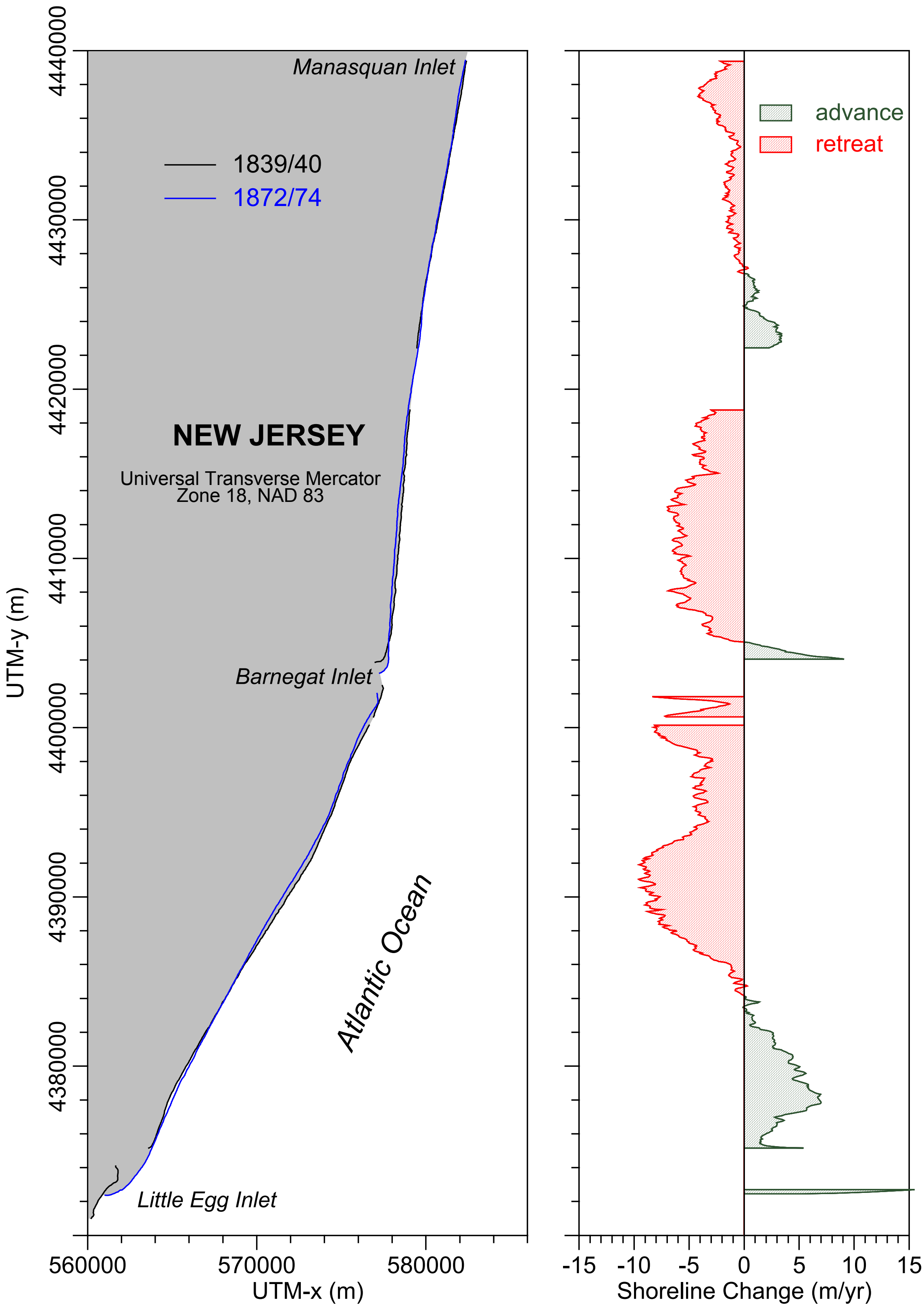

Figure 3-3. Shoreline position and change between Manasquan Inlet and Little Egg Inlet, New Jersey, 1839/40 to 1872/74.

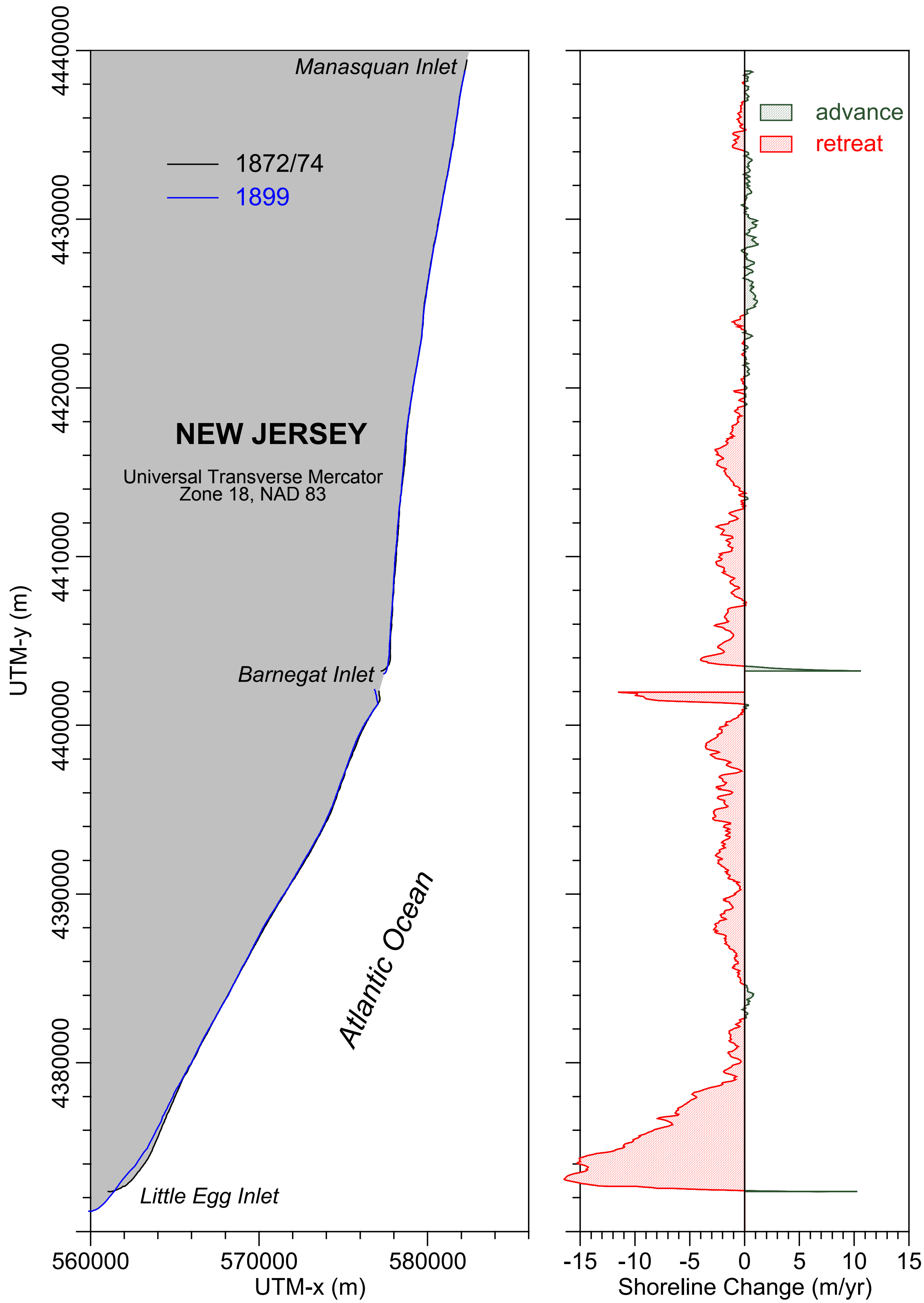

Figure 3-4. Shoreline position and change between Manasquan Inlet and Little Egg Inlet, New Jersey, 1872/74 to 1899.

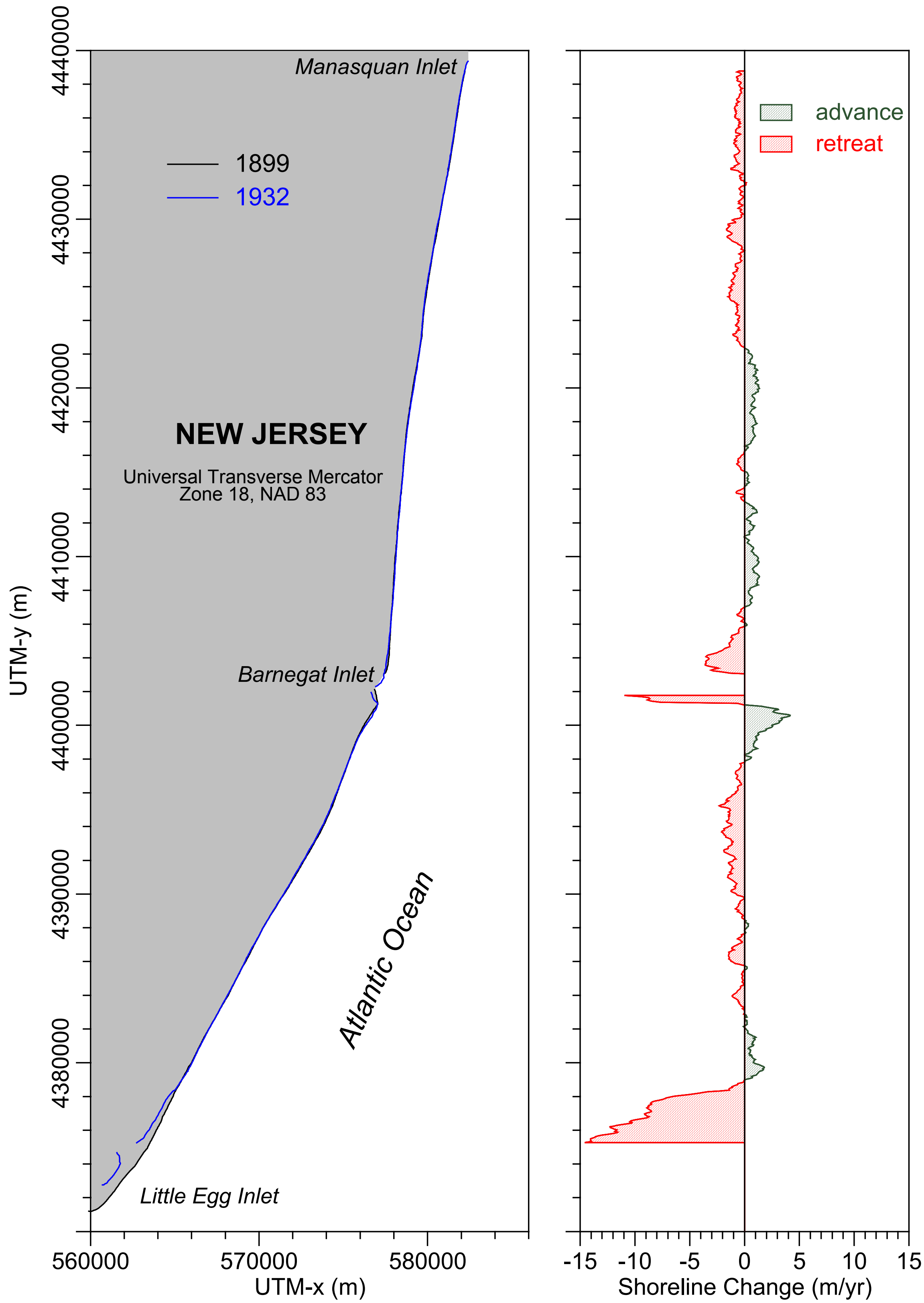

Figure 3-5. Shoreline position and change between Manasquan Inlet and Little Egg Inlet, New Jersey, 1899 to 1932.

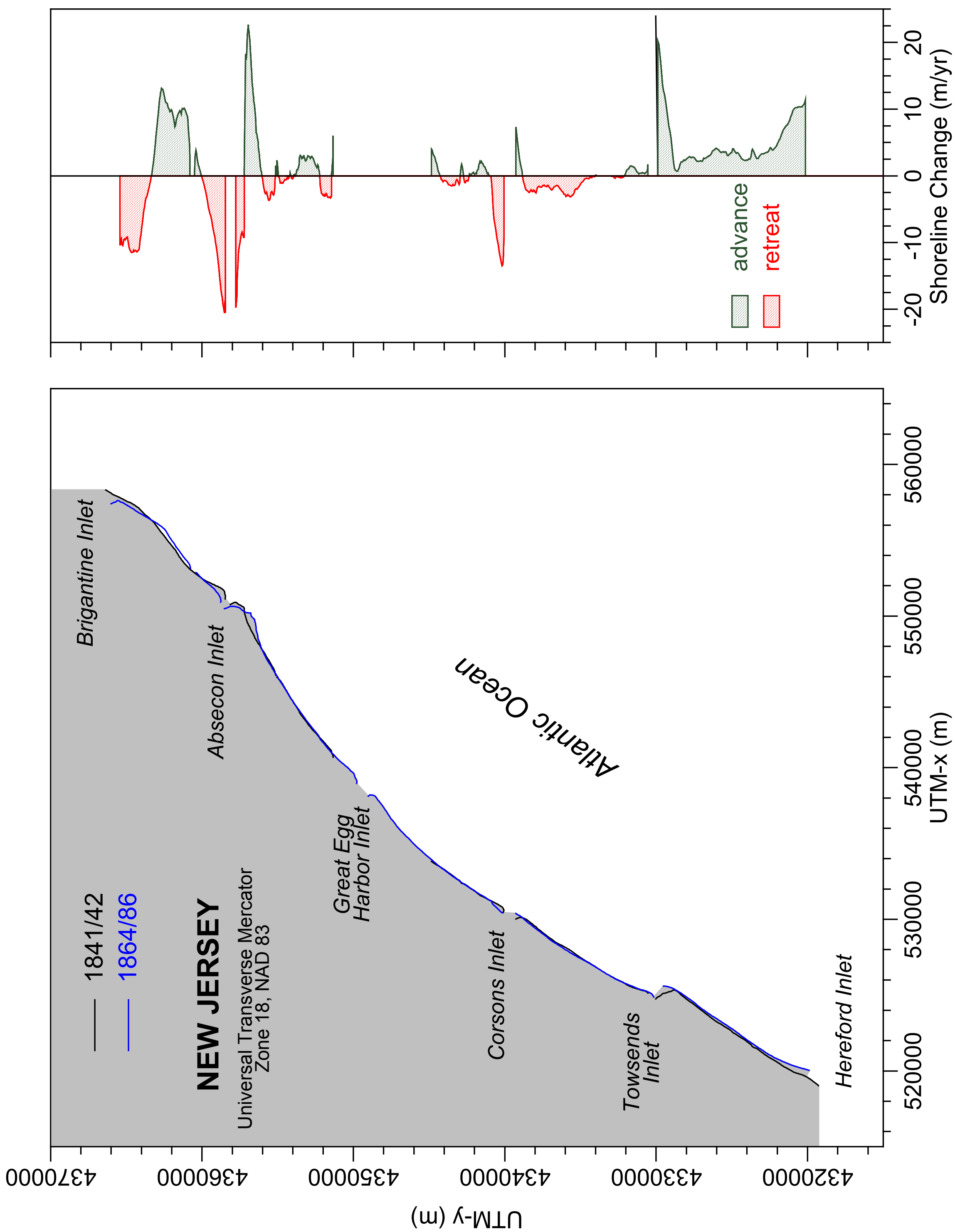

Figure 3-6. Shoreline position and change between Brigantine Inlet and Hereford Inlet, New Jersey, 1841/42 to 1864/86.

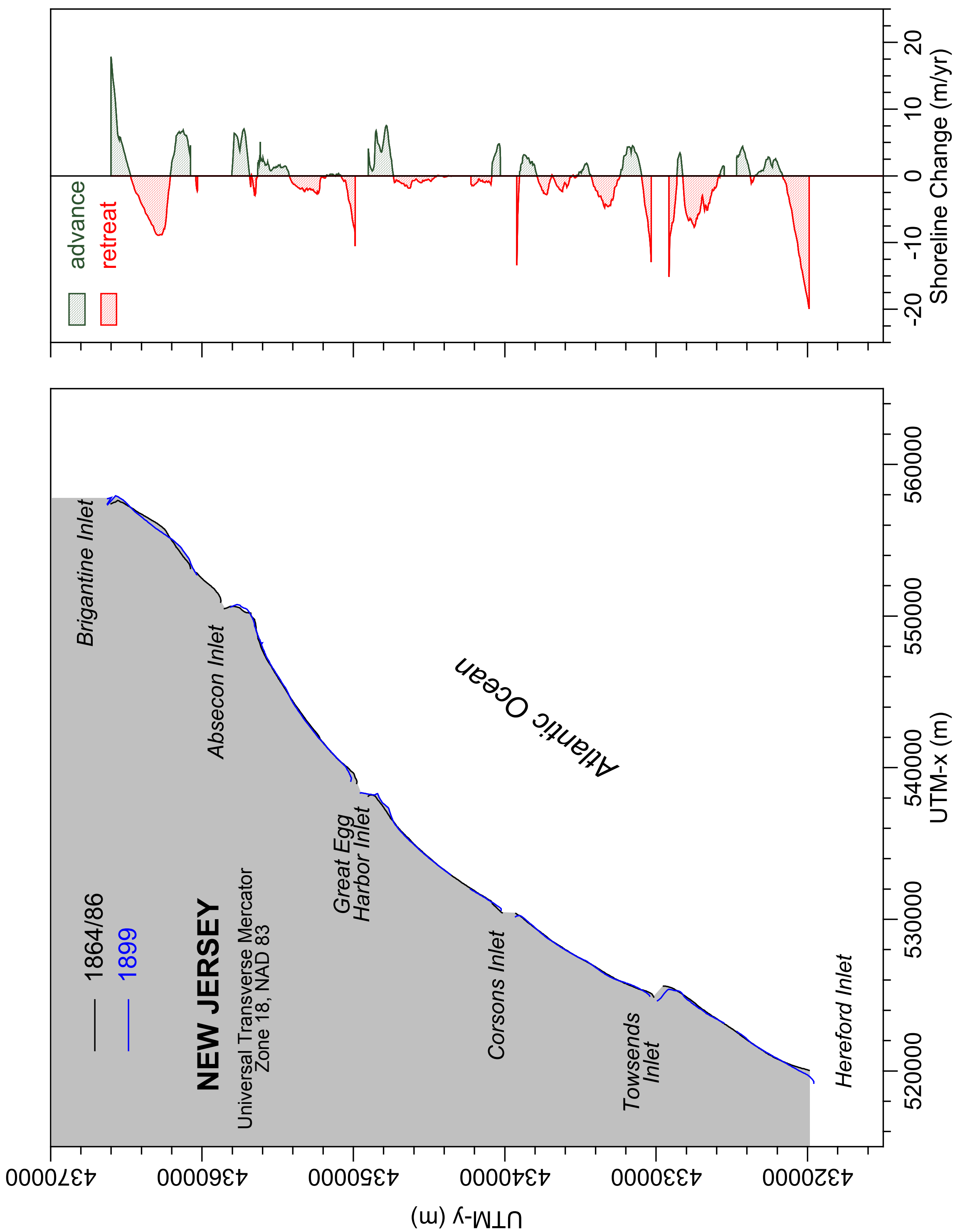

Figure 3-7. Shoreline position and change between Brigantine Inlet and Hereford Inlet, New Jersey, 1864/86 to 1899.

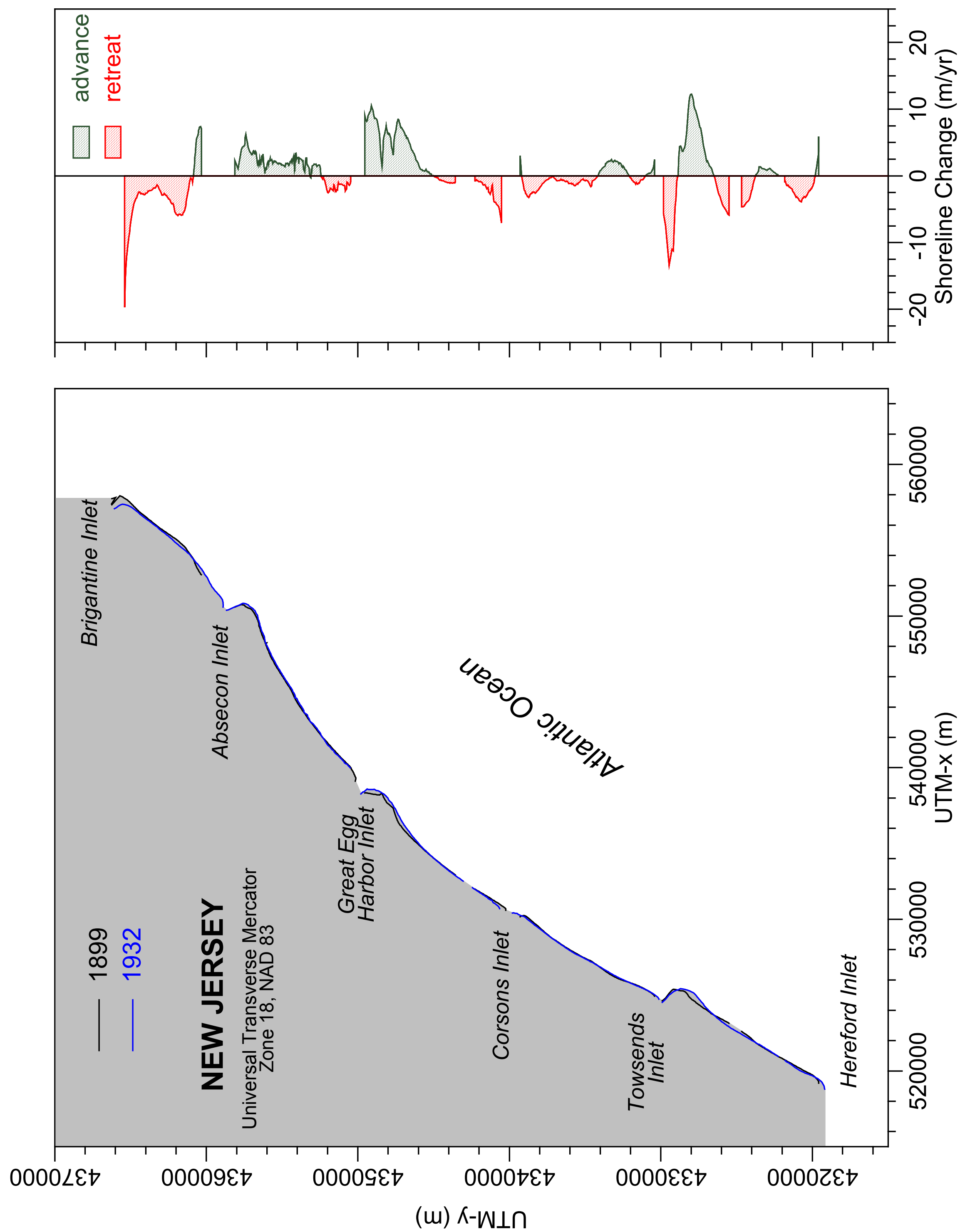

Figure 3-8. Shoreline position and change between Brigantine Inlet and Hereford Inlet, New Jersey, 1899 to 1932.

retreat dominate regional coastal change, whereas average change only summarizes the mathematical balance between these peaks. An independent summary of average shoreline advance (3.0 m/yr) and recession (-2.2 m/yr) documents this trend.

3.1.3.2 1932 to 1977

The period 1932 to 1977 represents the modern time interval for quantifying shoreline change, when aerial photography was used for mapping shoreline position and beach nourishment was active. In 1932, the beach near Little Egg Inlet contained a storm breach that occurred between 1899 and 1932. By 1950/51, the south end of Long Beach Island had migrated 1.1 km to the south (about 60 m/yr; see Figure 3-9). Except at beaches adjacent to inlets, shoreline changes between 1932 and 1950/51 were relatively small (average change = -0.1 m/yr; average shoreline retreat and advance values equal -0.8 and 0.6 m/yr, respectively.). Updrift deposition and downdrift erosion adjacent to Barnegat Inlet recorded the greatest magnitude of change (-12 to 15 m/yr), although the distance over which changes occurred was small.

From 1950/51 to 1977, average shoreline change between Manasquan and Little Egg Inlets was 0.34 m/yr. Except for shoreline movements adjacent to Barnegat and Little Egg Inlets, variations in shoreline movement were relatively small (Figure 3-10). Shoreline recession along the southern shore of Long Beach Island marked the greatest change in the area; however, island growth to the south resulted in 0.9 km of new beach. An apparent cycle of island growth and destruction is illustrated when comparing incremental changes in shoreline position at Little Egg Inlet between 1839/40 and 1977. The rapid rate of southward growth of Long Beach Island indicates a strong southward-directed longshore sediment transport system.

Shoreline changes south of Brigantine Inlet remained quite variable between 1932 and 1950/51. Peaks in shoreline recession and advance on either side of inlets dominate patterns of change; however, significant beach changes between entrances have great impacts on average shoreline change (Figure 3-11). The average rate of change between Brigantine and Hereford Inlets for the period 1932 to 1950/51 is about 0.3 m/yr. Variability in change measurements is reflected by a standard deviation value of $\pm$3.2 m/yr, and average change by direction is -2.4 and 2.3 m/yr. In this case, average change rates for the entire coastal area provide little insight into the processes causing erosion and accretion. Potential beach nourishment activities require an understanding of absolute beach response relative to average change.

For the period 1950/51 to 1977, greatest changes again were associated with beaches adjacent to inlets. Overall, the magnitude of shoreline advance peaks (14 to 20 m/yr) were greater than those related to shoreline recession (-10 to -12 m/yr; Figure 3-12). This trend is reflected in the average shoreline change rate (1.1 m/yr), as well as with average change by direction values (-1.1 to 2.1 m/yr). Between 1986 and 1992, many beaches between Brigantine and Hereford Inlets were nourished with thousands of cubic yards of beach sand (Uptegrove et al., 1995). Between 1950 and 1977, the USACE and the State of New Jersey placed millions of cubic yards of beach fill within this coastal area (e.g., USACE, 1996, 1997). These beach nourishment projects helped stabilize eroding coasts and increased beach width since the 1950s.

3.1.3.3 Cumulative Shoreline Position Change (1839/42 to 1977)

Shoreline position change between 1839/40 and 1977 documents significant shoreline recession along much of the beach between Manasquan and Little Egg Inlets (Figure 3-13). Average shoreline change between Manasquan and Barnegat Inlets was -0.6 m/yr ($\sigma = \pm0.8$ m/yr). However, for the beaches between Barnegat and Little Egg Inlets, average shoreline

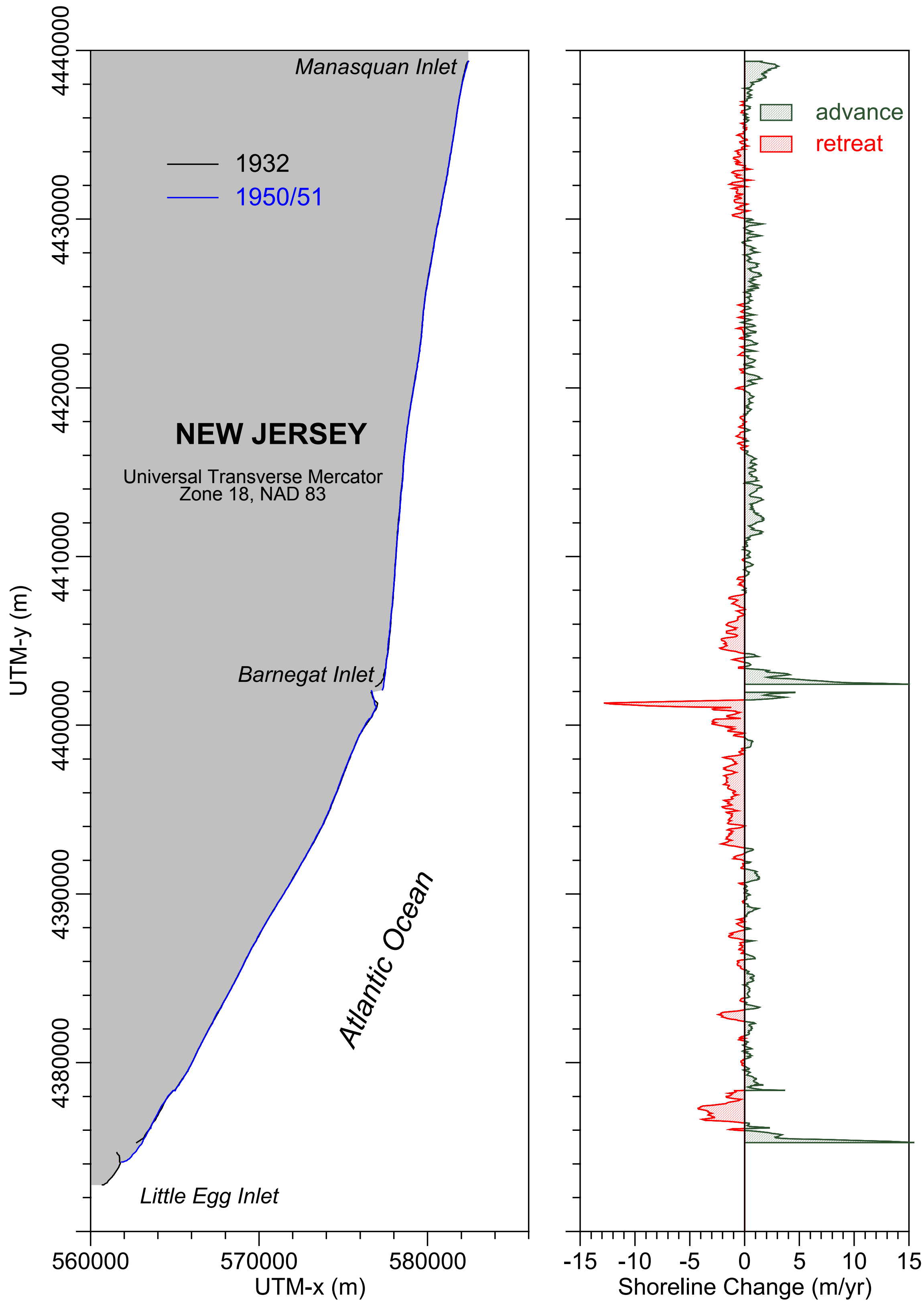

Figure 3-9. Shoreline position and change between Manasquan Inlet and Little Egg Inlet, New Jersey, 1932 to 1950/51.

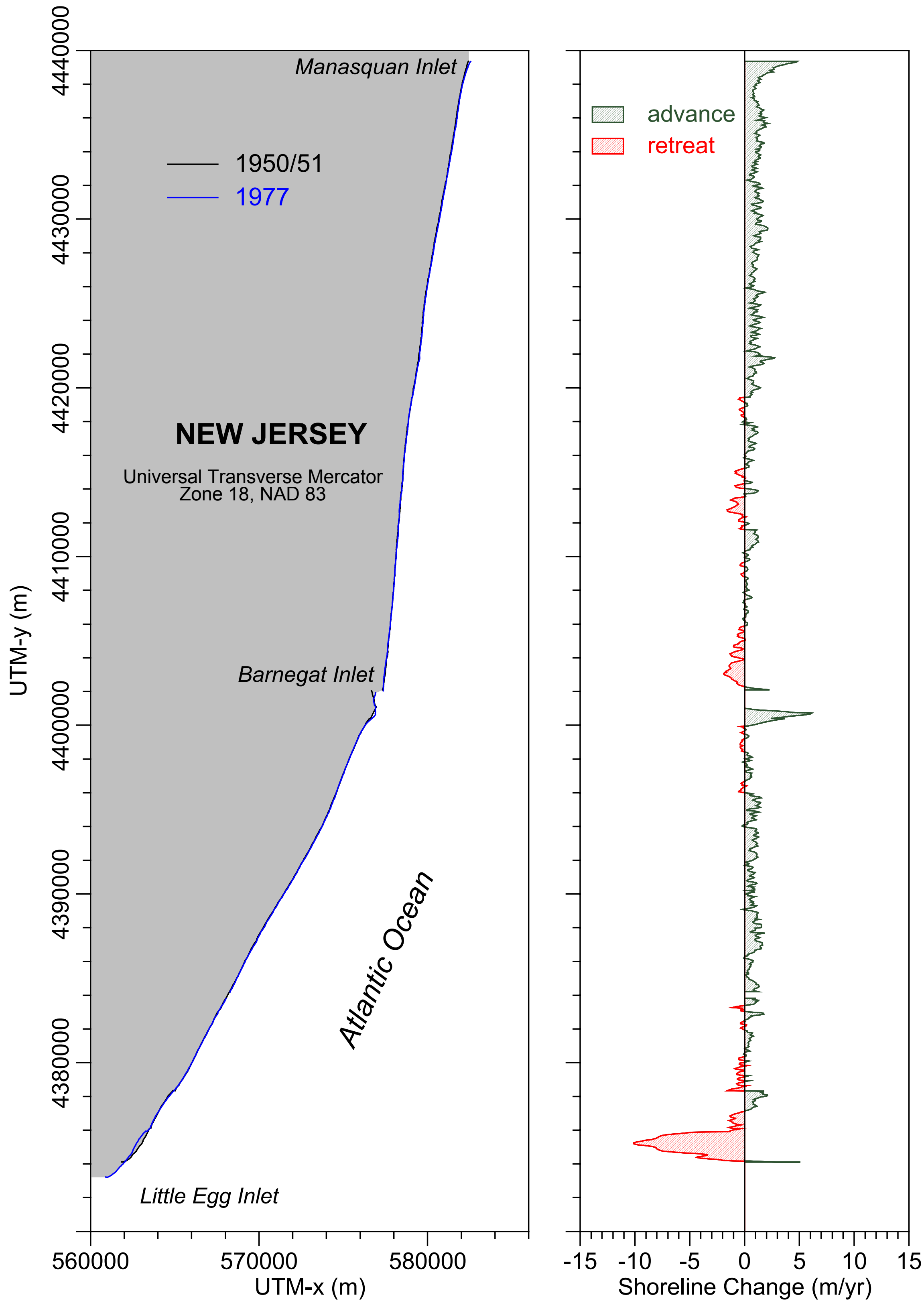

Figure 3-10. Shoreline position and change between Manasquan Inlet and Little Egg Inlet, New Jersey, 1950/51 to 1977.

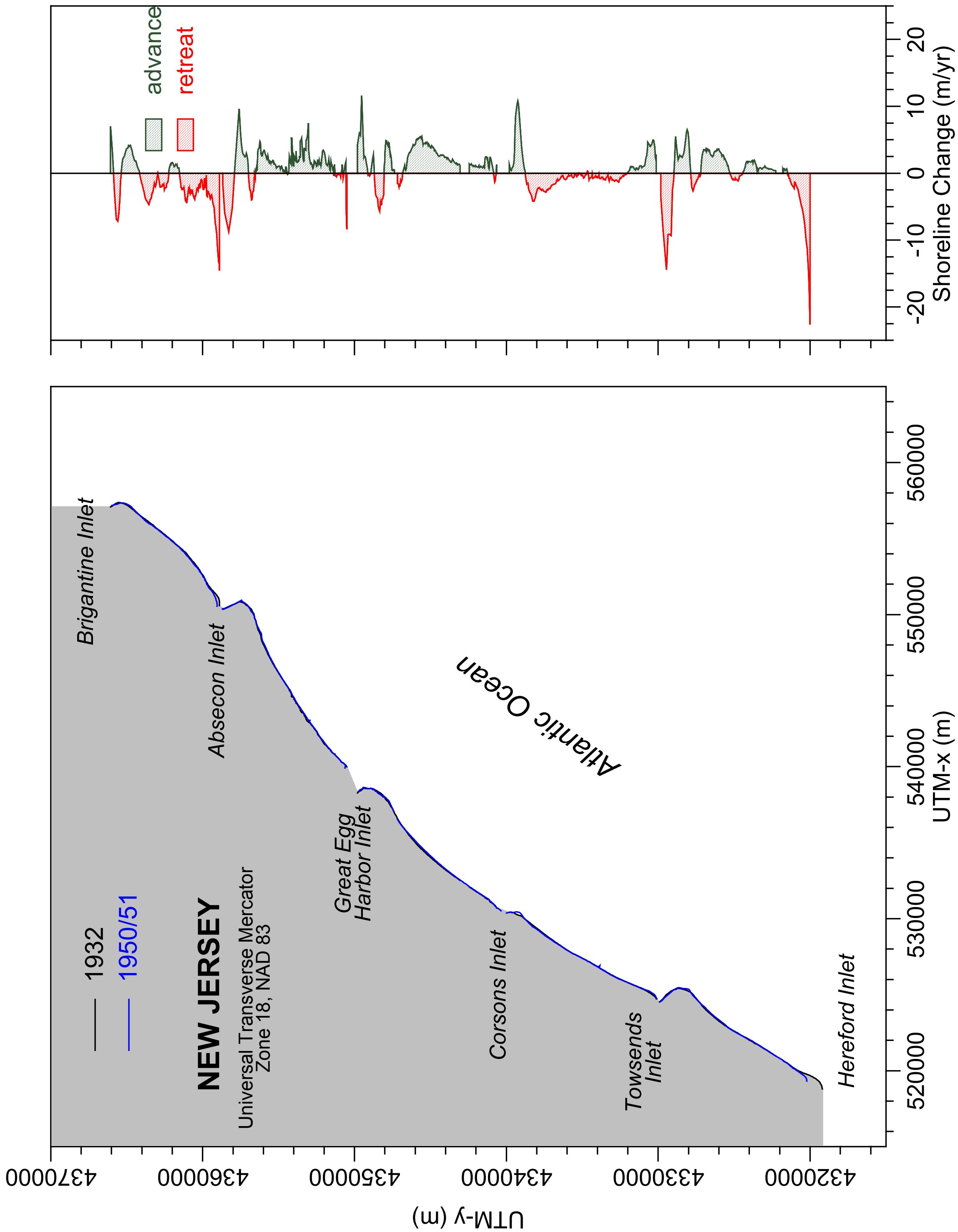

Figure 3-11. Shoreline position and change between Brigantine Inlet and Hereford Inlet, New Jersey, 1932 to 1950/51.

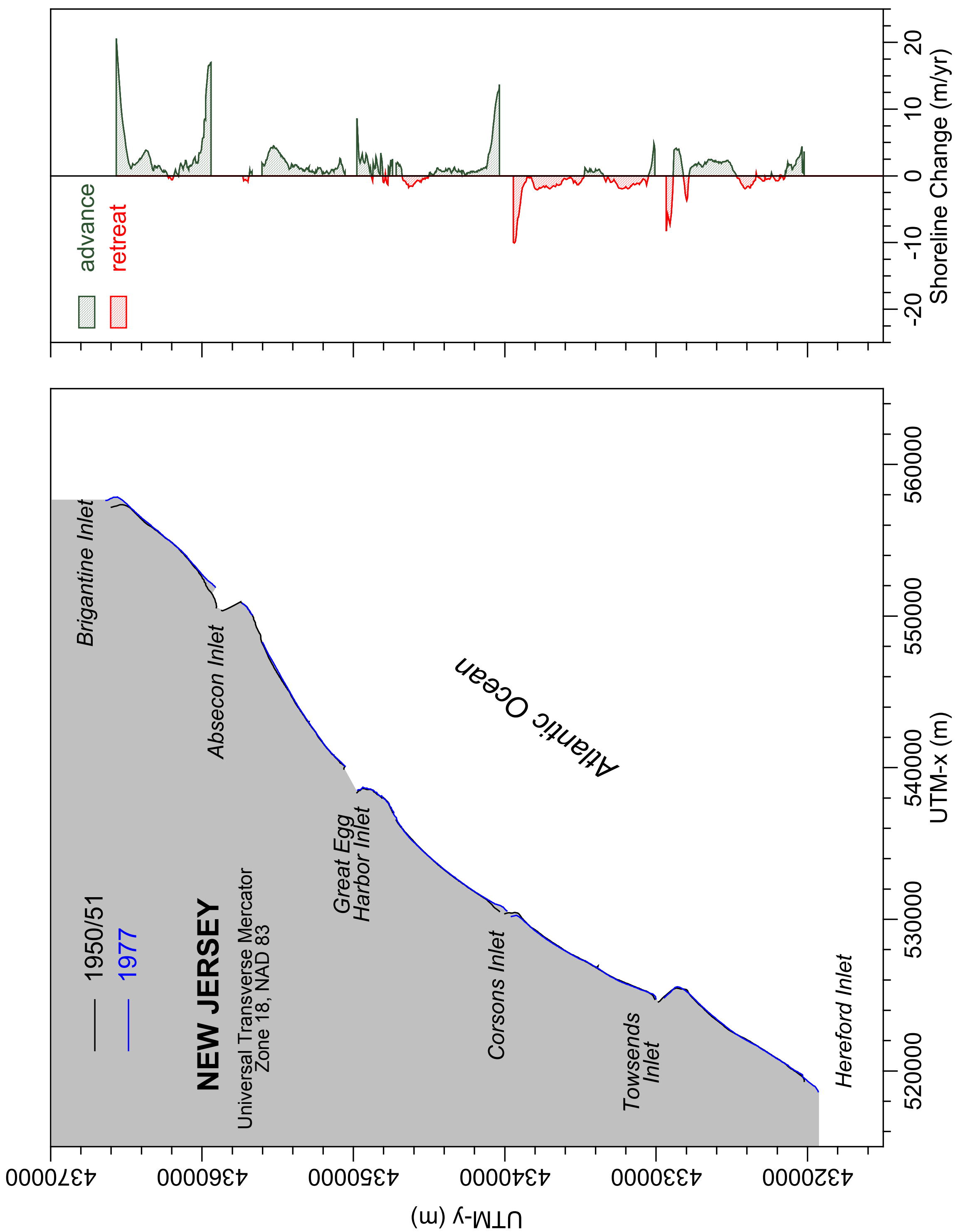

Figure 3-12. Shoreline position and change between Brigantine Inlet and Hereford Inlet, New Jersey, 1950/51 to 1977.

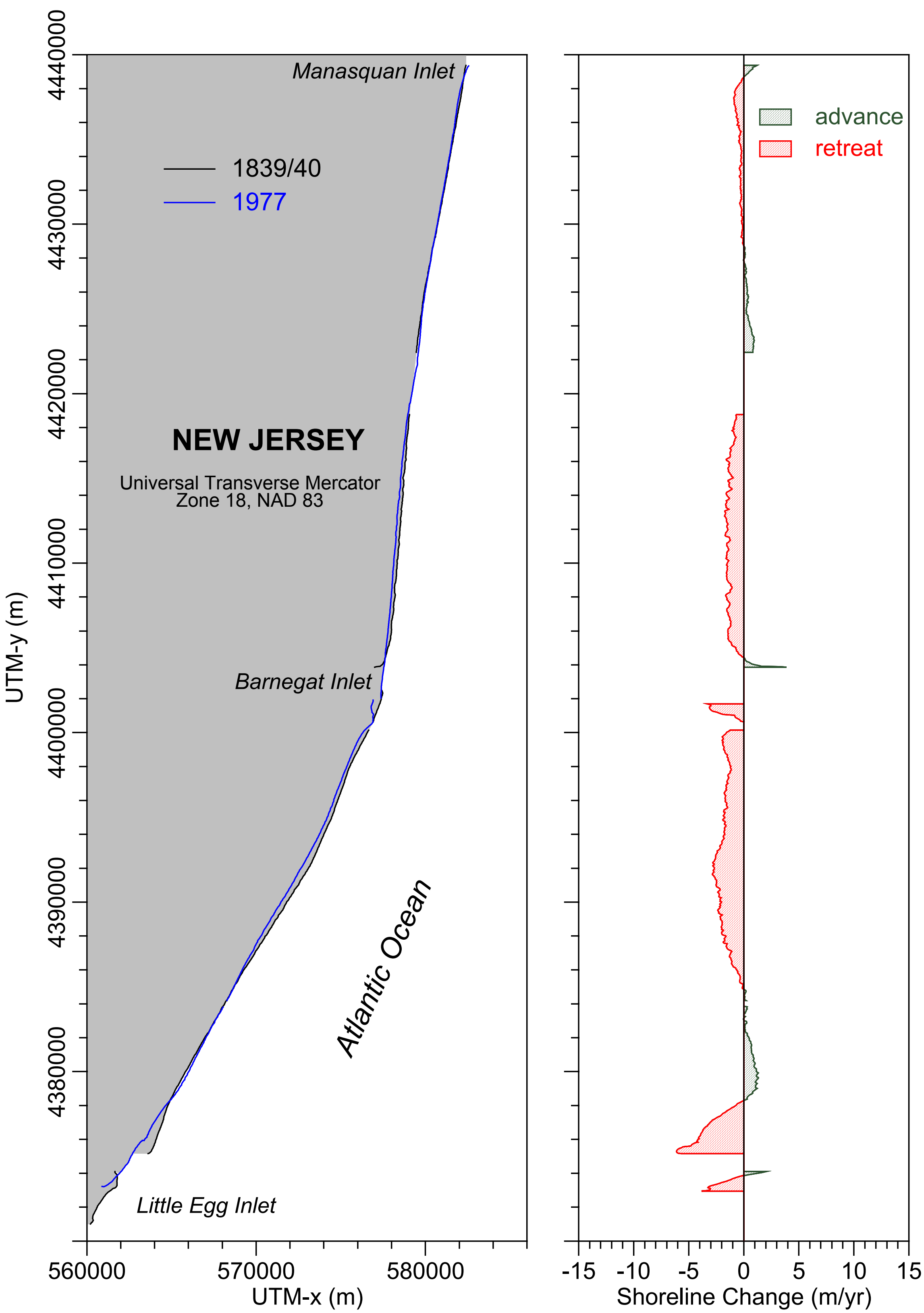

Figure 3-13. Shoreline position and change between Manasquan Inlet and Little Egg Inlet, New Jersey, 1839/40 to 1977.

recession more than doubled to -1.3 m/yr ($\sigma = \pm 1.5$ m/yr). For the entire length of coast, the variability in measurements was relatively low, as indicated by low standard deviation values. Although the southern part of Long Beach Island, north of Little Egg Inlet, showed the greatest net shoreline recession for the 137-yr period of record, the southern terminus of the island grew approximately 1.9 km to the southwest (about 14 m/yr) during this same time period. Sequential shoreline changes recorded between 1839/40 and 1977 suggest that storm events play a primary role in beach and inlet evolution along southern Long Beach Island. In fact, at Barnegat Inlet, Island Beach (north of the inlet) migrated 1.8 km to the south during the same time period. These data indicate that net longshore sediment transport is to the south. The change in shoreline orientation between Island Beach and Long Beach Island may be partially responsible for the increase in shoreline recession south of Barnegat Inlet and the rapid southward growth of Long Beach Island.

South of Brigantine Inlet to Hereford Inlet, net shoreline change was relatively small between 1841/42 and 1977 (Figure 3-14). Greatest changes occurred near the inlets, and net shoreline advance dominated beach response (0.3 m/yr [$\sigma = \pm 1.4$ m/yr]). The trend in shoreline change from north to south was more variable than that to the north, and the magnitude of change was less. This may reflect the addition of numerous beach fills starting in the 1940s. Southward growth of the beaches in southern New Jersey mimic those to the north, illustrating that the dominant direction of longshore sediment transport for the entire coast is to the south.

3.2 NEARSHORE BATHYMETRY CHANGE

3.2.1 Bathymetry Data Base and Potential Errors

Seafloor elevation measurements collected during historical hydrographic surveys are used to identify changes in nearshore bathymetry for quantifying sediment transport trends relative to natural processes and engineering activities. Two USC&GS bathymetry data sets were used to document seafloor changes between 1843/91 and 1934/77. Temporal comparisons were made for an 85-km coastal segment from southern Long Beach Island (2 km north of Little Egg Inlet) to Cold Springs Inlet near Cape May. Data extend offshore to about the 30-m depth contour (about 30 km offshore). The survey sets consist of digital data compiled by the National Geophysical Data Center (NGDC) and analog information (maps) that were compiled in-house using standard digitizing procedures (see Byrnes and Hiland, 1994).

The first regional USC&GS bathymetric survey was conducted in 1843/91 (Table 3-4); data were registered in units of feet. Nearshore surveys were mapped at scales of 1:10,000 and 1:20,000, whereas offshore survey maps focused on regional data coverage at a scale of 1:40,000. The density of points was good for characterizing coastal and shelf topography; however, the most recent survey (1943/77) recorded many more points for describing surface characteristics for the same area. The 1843/91 offshore surveys contained an adequate number of depths along each survey line, and longshore spacing of lines was about 0.5 to 1 km. As such, depth values are reasonable for describing bathymetric features and compared well with the 1943/77 survey set. The 1943/77 bathymetry data are available as digital data from the NGDC.

As with shoreline data, measurements of seafloor elevation contain inherent errors associated with data acquisition and compilation. Potential error sources for horizontal location of points are identical to those for shoreline surveys (see Table 3-2). These shifts in horizontal position translate to vertical adjustments of about ±0.3 to 0.5 m based on information presented in USC&GS and USACE hydrographic manuals (e.g., Adams, 1942). Corrections to soundings for tides and sea level change introduce additional errors in vertical position of ±0.1 to 0.3 m.

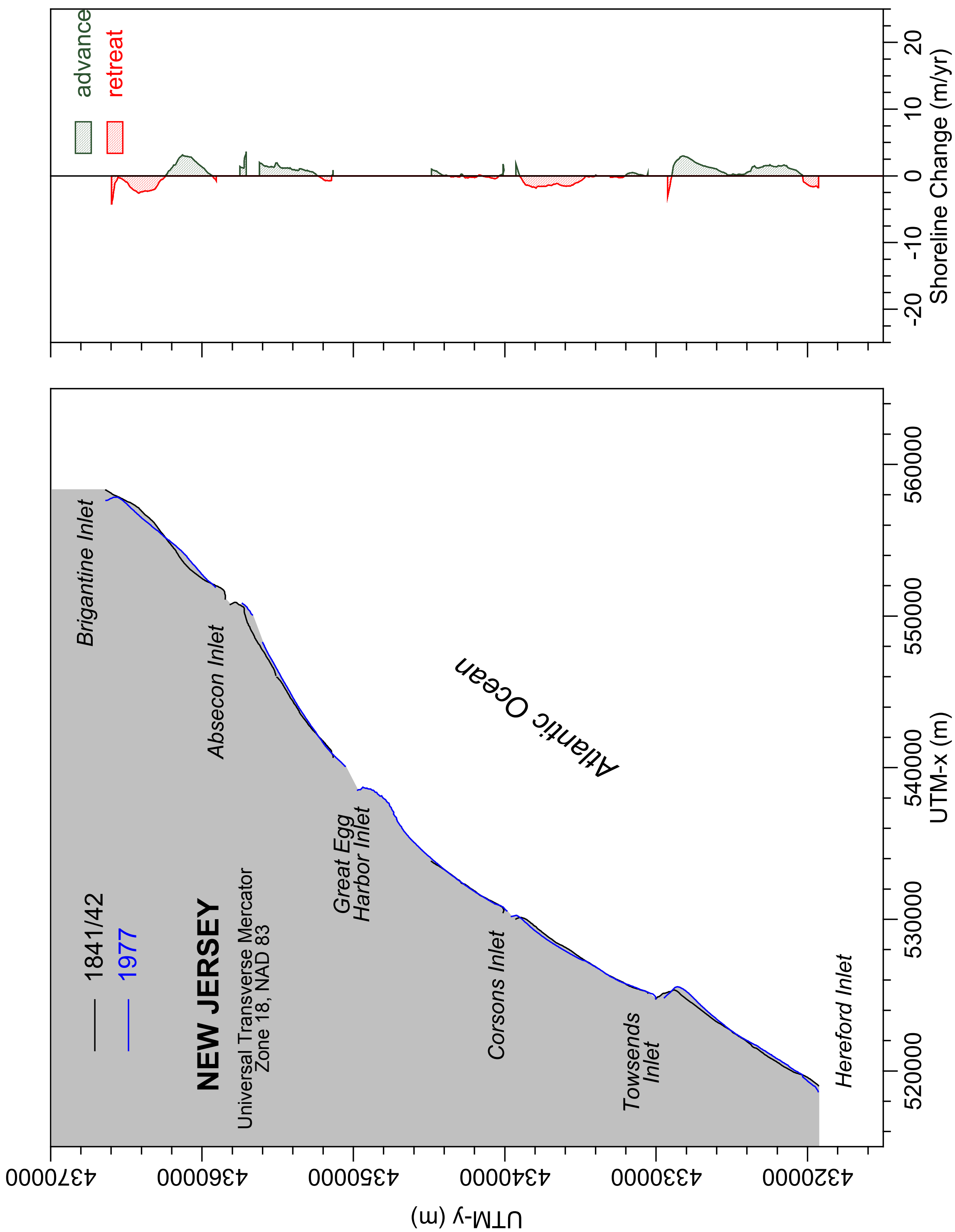

Figure 3-14. Shoreline position and change between Brigantine Inlet and Hereford Inlet, New Jersey, 1841/42 to 1977.

Table 3-4. Summary of bathymetry source data characteristics for the offshore area between Manasquan Inlet and Cape May, New Jersey.

Date	Data Source	Comments and Map Numbers
1843/91	USC&GS Hydrographic Sheets 1:10,000 (H-837, H-1158a, H-1158b, H-1578b, H-2164, H-2166) 1:20,000 (H-2165) 1:40,000 (H-116, H-1533, H-1696)	First regional bathymetric survey for offshore New Jersey; 1843 - offshore area from Little Egg Inlet to Cape May (H-116); 1864 - seaward of Absecon Inlet (H-837); 1872/74 - seaward of Little Egg Inlet and Brigantine Inlet (H-1158a, H-1158b); 1883/91 - Manasquan Inlet to Seaside Heights (H-1578b), Corsons Inlet to Hereford Inlet and offshore (H-1533, H-1696), seaward of Cape May Inlet, Hereford Inlet, and Townsends Inlet (H-2164, H-2165, H2166).
1934/88	USC&GS Hydrographic Sheets 1:10,000 (H-5615, H-6141, H-6145, H-6195, H-6196, H-6232, H-6236, H-6262, H-8219, H-8220, H-8675, H-8676) 1:20,000 (H-6136, H-6225, H-6226, H-6227, H-8222, H-9153, H-9312, H-9699, H-9700) 1:40,000 (H-6188, H-6190, H-6224, H-6271, H-9531, H-9534, H-9452, H-9546, H-9552, H-9573)	Most recent offshore regional bathymetric survey; 1934/40 - Manasquan Inlet to Barnegat Inlet (H-5615, H-6136, H-6141, H-6188, H-6190), Barnegat Inlet to Great Egg Inlet (H-6145, H-6195, H-6196, H-6225, H-6271, Great Egg Inlet to Cape May Inlet (H-6226, H-6227, H-6232, H-6236, H-6262, H-6264); 1954/62 - Surf City to Ocean City (H-8219, H-8220, H-8222, H-8675, H-8676); 1970/77 - offshore New Jersey (H-9153, H-9312, H-9531, H-9534, H-9542, H-9546, H-9552, H-9573, H-9699, H-9700).

Finally, the accuracy of depth measurements adds error that is variable depending on the measurement method. It is estimated that the combined root-mean-square error for bathymetric surface comparisons between 1843/91 and 1943/77 is about $\pm$0.6 m. This estimate was used to denote areas of no significant change on surface comparison maps.

Because seafloor elevations are temporally and spatially inconsistent for the entire data set, adjustments to depth measurements were made to bring all data to a common point of reference. These adjustments include changes in relative sea level with time and differences in reference vertical datums. Vertical adjustments were made to each data set based on the time of data collection. All depths were referenced to NGVD and projected average sea level for 1977. The unit of measure for all surfaces is meters, and final values were rounded to decimeters before cut and fill computations were made.

3.2.2 Digital Surface Models

Historical bathymetry data within the study area provide geomorphic information on characteristic surface features that form in response to dominant coastal processes (waves and currents) and relative sea level change. Comparing two or more surfaces documents net sediment transport patterns relative to incident processes and sediment supply. The purpose for conducting this analysis throughout the study area is to document net sediment transport trends on the shelf surface and to quantify the magnitude of change to calibrate the significance of short-term wave and sediment transport numerical modeling results. Net sediment transport rates on the shelf were determined using historical data sets to address potential infilling rates for sand borrow sites.

3.2.2.1 1843/91 Bathymetric Surface

Bathymetry data for the period 1843/91 were combined with the 1839/42 and 1872/74 shoreline data to create a continuous surface from the shoreline seaward to about the 30-m depth contour (NGVD). The most prominent geomorphic features throughout the study area are the ebb-tidal deltas associated with inlets and the presence of linear offshore sand ridges south of Townsends Inlet (Figure 3-15). A series of well-defined ebb shoals exist for Little Egg, Absecon, Corsons, Townsends, Hereford, and Cold Springs Inlets (data were not available for Great Egg Harbor Inlet, but similar features were likely present at this entrance as well). Shoreline change data for this area indicated dominant southward-directed longshore sediment transport, and the predominance of shallow shoals on the north side of these entrances supports this conclusion.

A series of relatively small linear sand ridges are present southwest of Little Egg Inlet near the Federal-State OCS boundary. These prominent features exist landward of the Federal-State boundary as well and represent a primary offshore sand source for beach nourishment or construction aggregates. The presence and characteristics of these features are best defined south of Corsons Inlet. The continental shelf offshore Sea Isle City, Townsends Inlet, Avalon, Stone Harbor, Hereford Inlet, and Wildwood contain extensive shoreface sand ridges oriented at oblique angles to the modern shoreline. The origin of these sand ridges has been associated with lateral inlet migration along a landward migrating shoreline (McBride and Moslow, 1991), suggesting that sediment associated with offshore sand ridges is compatible with modern beach deposits. Historical shoreline change data illustrate lateral island migration and shoreline retreat between 1839/42 and 1977, providing a mechanism for oblique sand ridge formation on the upper shoreface. Geological data from the NJDEP (Uptegrove et al., 1995) illustrate that shoreface sand ridges are the most viable features for beach sand on the continental shelf.

A little less than half of the study area did not have accurate bathymetric data coverage to create a continuous surface for the 1843/91 timeframe. Historical bathymetry data are available from the NOS for the area between Manasquan Inlet and Little Egg Inlet for this time period. However, after extensive evaluation regarding the reliability of measurements in this area, it was determined that depth values could not be used to accurately describe surface morphology or quantify sediment transport patterns.

3.2.2.2 1934/77 Bathymetric Surface

General characteristics of the 1934/77 bathymetric surface are similar to those of the 1843/91 surface with a couple of exceptions (Figure 3-16). First, the area of coverage includes the offshore zone north of Little Egg Inlet to Manasquan Inlet. Second, geomorphic features are better defined because the number of data points describing the surface is larger. The general shape and position of shoals is consistent for both surfaces. However, the detail associated with shoals along the coast (generally at inlets) and linear sand ridges on the shoreface provides an understanding of the relationship between potential sand resource areas and coastal sedimentation processes. All potential sand resource areas, with the exception of F2, exist on offshore linear sand ridges, which have been linked with ancient inlet deposits during lower sea level (McBride and Moslow, 1991).

With the availability of continental shelf bathymetry data from Manasquan to Cold Springs (Cape May) Inlets, a general trend in shelf morphology emerges. The slope of the shelf surface north of Little Egg Inlet is noticeably steeper than that seaward of the barrier islands in Cape May County (Figure 3-16). For example, the 20-m depth contour seaward of the beaches south of Manasquan Inlet exists approximately 3 km offshore. Seaward of Townsends Inlet (west of Sand Resource Area A2), the same depth contour is about 12 km offshore. As a result, there is

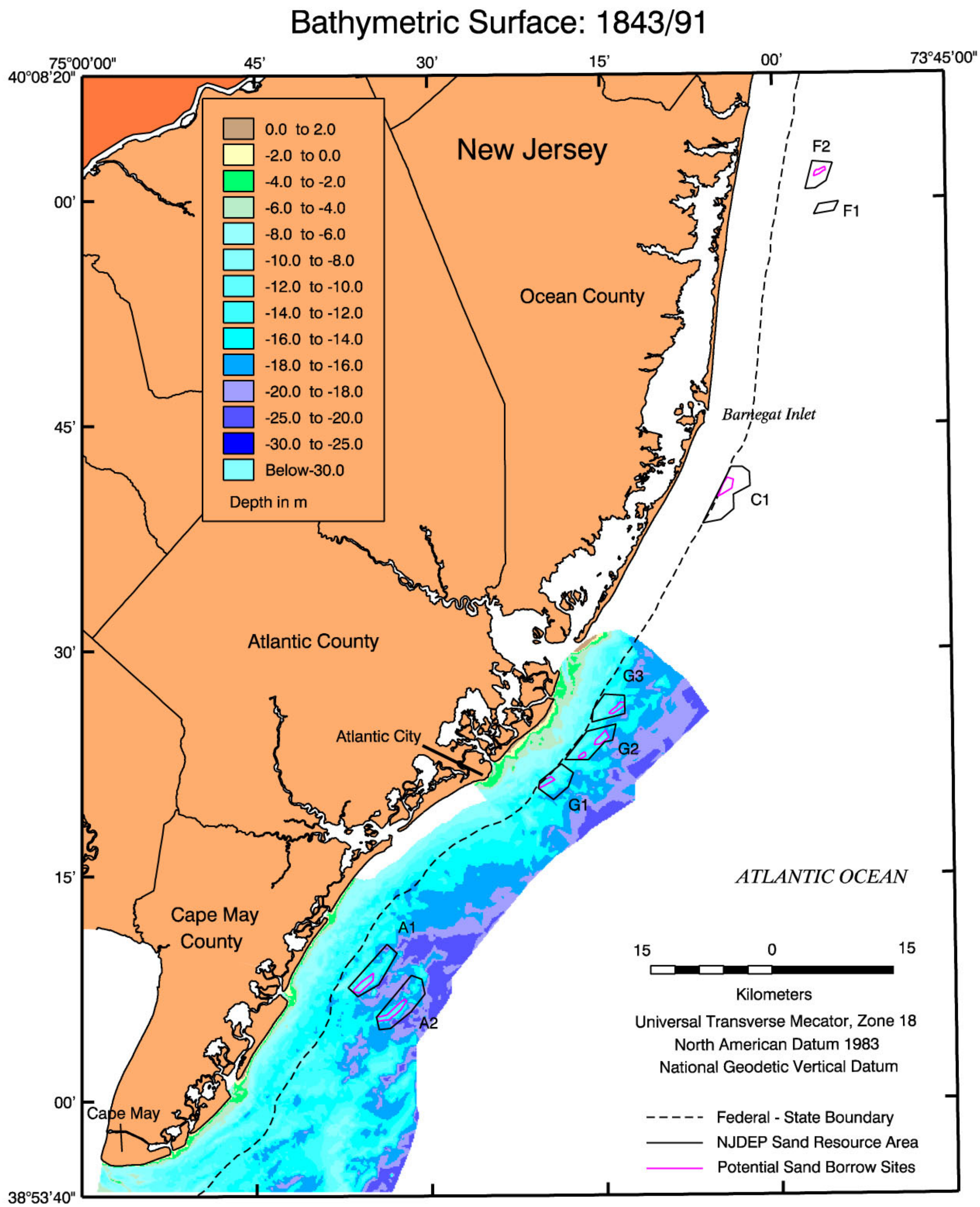

Figure 3-15. Nearshore bathymetry (1843/91) for offshore New Jersey.

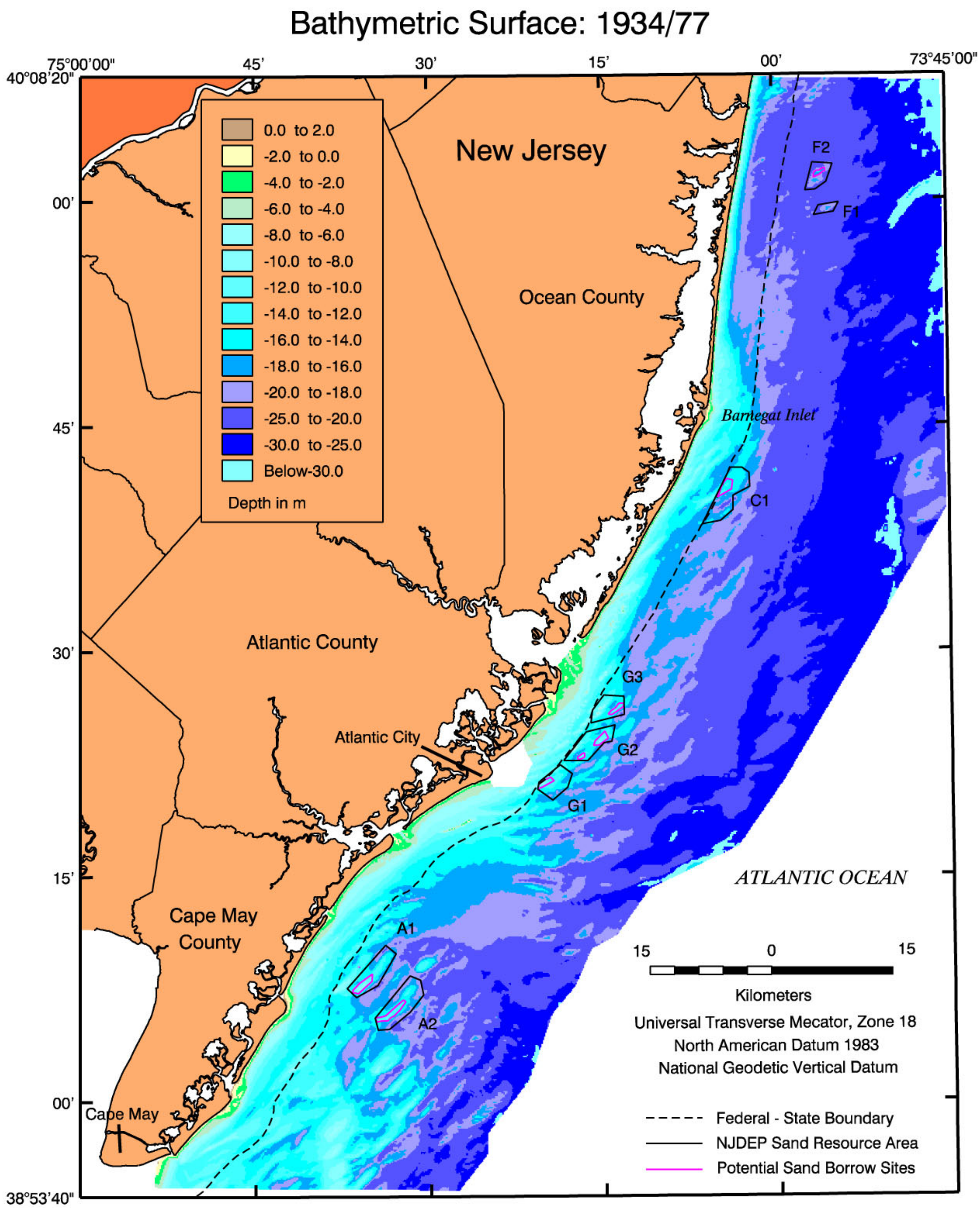

Figure 3-16. Nearshore bathymetry (1934/77) for offshore New Jersey.

an absence of linear sand ridges north of Barnegat Inlet and an abundance of sand ridges seaward of the southern barrier island chain (steep shelf gradient, small horizontal displacement of water surface during sea level rise, greater reworking of shelf surface, straight and parallel contours; low shelf gradient, large horizontal displacement of water surface during sea level rise, reworking of shelf surface over larger area, contours reflect ancient beach deposits).

The shelf surface seaward of Barnegat Inlet illustrates the influence of tidal inlet sedimentation processes on shelf morphology. The delta-shaped bulge in contours, marked by the 12-m depth contour, documents the longshore extent (about 20 km) of inlet-influenced sedimentation on shelf morphology. The 12-m depth contour again bulges seaward of the Little Egg-Brigantine-Absecon Inlets area, backed by an estuary with a substantial tidal prism. South of this region, the 12-m depth contour exists landward of the Federal-State boundary, except at offshore shoal deposits. Inlet sedimentation processes in this area are important to coastal evolution, but small bays behind the southern islands result in small tidal prisms that produce greater geomorphic changes on the upper shoreface than on the continental shelf. Offshore linear sand ridges dominate the shelf surface in southern New Jersey, creating ideal locations for potential sand borrow sites for beach nourishment.

3.2.3 Shelf Sediment Transport Dynamics

Although the general characteristics of bathymetric surfaces appear similar for 1843/91 and 1934/77, a digital comparison of these surfaces yields a difference plot that isolates areas of erosion and accretion for documenting sediment transport patterns and quantifying trends (Figure 3-17). The most significant changes occurring during this 50- to 130-yr interval were associated with deposition (and erosion) at and seaward of the inlets along the southern New Jersey barrier islands, and alternating patterns of erosion and deposition across the shelf surface in the northeast-southwest-trending sand ridge field from Little Egg Inlet to Cold Springs (Cape May) Inlet.

Fluid flow and sediment transport at and seaward of the inlets separating barrier islands in southeastern New Jersey produce the most pronounced geomorphic changes throughout the study area. Tidal exchange through these inlets mobilizes substantial quantities of sediment near the coastline and on the upper shoreface, resulting in spit growth along the downdrift margin of islands and shoal migration at and adjacent to entrances, illustrated as areas of erosion (yellow to brown) and deposition (green) on Figure 3-17. Polygons of erosion and deposition generally follow contour shapes defined by shoals and troughs on the continental shelf. Shelf bathymetry seaward of the Federal-State boundary and east-southeast of Great Egg Harbor Inlet illustrates the lowest relief features south of Little Egg Inlet (see Figure 3-16), and bathymetric change is minor. Conversely, offshore areas north and south of this zone illustrate a more active surface (Figure 3-17) where numerous shoreface sand ridges reside. Alternating zones of accretion and erosion reflect the migration of continental shelf sand ridges.

Prominent areas of sediment deposition (green polygons) on the upper shoreface are present along the shoreline south of Townsends and Hereford Inlets, and just south of Little Egg Inlet. This trend likely is present at Absecon and Great Egg Harbor Inlets as well, but lack of data does not allow verification of this deposition pattern. These areas of sediment accretion are associated with ebb-tidal shoal migration and sediment bypassing at entrances in response to southward-directed longshore sediment transport. Other areas of deposition on the continental shelf are recognized as relatively small linear features that reflect the southern movement of sand ridges under the influence of nearshore waves and currents. Often, updrift

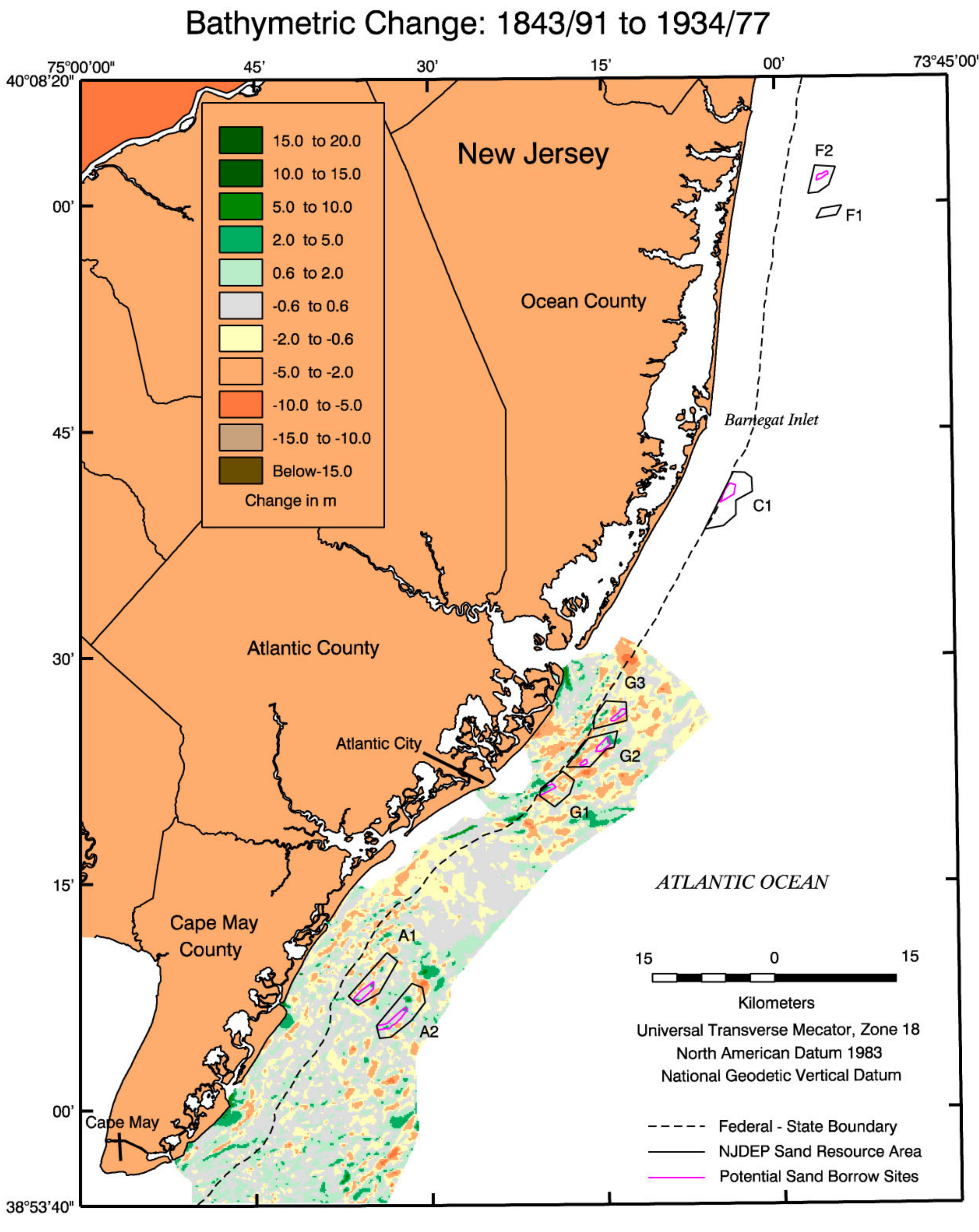

Figure 3-17. Nearshore bathymetry change (1843/91 to 1934/77) for the southeastern New Jersey shoreface.

zones of erosion are associated with downdrift linear deposits, illustrating the historical movement of shoals on the shelf surface. The greatest amount of bathymetric change on the shelf surface exists seaward and between Little Egg and Absecon Inlets.

Sand volume change calculations for zones of accretion and erosion along the shore and on the shelf surface are used to estimate net sand transport rates (see Sections 3.2.4 and 3.2.5). Historical transport rates are used to calibrate simulations of borrow site infilling and nearshore sand transport (Section 5.2).

3.2.4 Magnitude and Direction of Change

Patterns of seafloor erosion and accretion on the continental shelf seaward of the New Jersey coast documented the net direction of sediment transport throughout the study area (Figure 3-17). For the period 1843/91 to 1934/77, net sediment movement is from north to south. This direction of transport is consistent with historical shoreline change trends and channel dredging practice at entrances along the New Jersey coast (any sidecasting, nearshore, or offshore dumping is to the south of inlets). Although overall trends are helpful for assessing potential impacts of sand extraction from the OCS, the specific purpose of the historical bathymetric change assessment is to quantify sediment erosion and accretion and to derive transport rates specifically related to potential sand extraction sites. Of the eight sand resource areas, seven were chosen for evaluating sand extraction scenarios based on minimum beach replenishment requirements and NJDEP geologic data. Area F1 in the northern portion of the study area was not evaluated as a sand borrow area because the volume of sediment available for sand mining was not adequate for potential beach nourishment projects.

For Resource Areas F2 and C1, regional bathymetric change data were not available for quantifying potential sediment transport rates. This is particularly a problem for Area F2 where the sand resource area is in 20 to 25 m of water. Water depths at Resource Area C1 are very similar to those at Areas G1, G2, and G3. For these resource areas, sediment erosion zones parallel to shoreface ridges indicate that potential transport rates available for infilling any proposed borrow sites in the areas would range from about 62,000 to 125,000 m^3/yr (5.6 to 14.0 MCM over about 90 to 120 years; Figure 3-18). This calculation assumes that sediment eroded from areas nearby potential borrow sites reflect the rate at which material would be available for infilling the borrow sites. Because Area C1 is similar in character to Areas G1, G2, and G3, potential transport rates for Areas G1, G2, and G3 are considered representative for assessing infilling at Area C1.

For Resource Areas A1 and A2, sediment erosion zones parallel to shoreface ridges again were used as indicators of potential transport rates available for infilling proposed sand borrow sites in the resource areas (Figure 3-19). Total sediment erosion over a 51-yr period ranged from 8.0 to 10.0 MCM, or about 160,000 to 200,000 m^3/yr. These rates are approximately two times those documented to the north, reflecting a more dynamic offshore environment seaward of the southern barrier island chain. Again, this calculation assumes that sediment eroded from areas nearby potential borrow sites reflects the rate at which material would be available for infilling the borrow sites. The dredging geometry (depth to width to length) for each potential borrow site, as well as the type of sediment available for infilling, are controlling factors for determining sediment infilling (see Section 5.2).

3.2.5 Net Longshore Sand Transport Rates

Well-defined zones of erosion and accretion along the shoreline are documented in Figure 3-17 as regions of littoral sand transport along the barrier island chain of southern New Jersey.

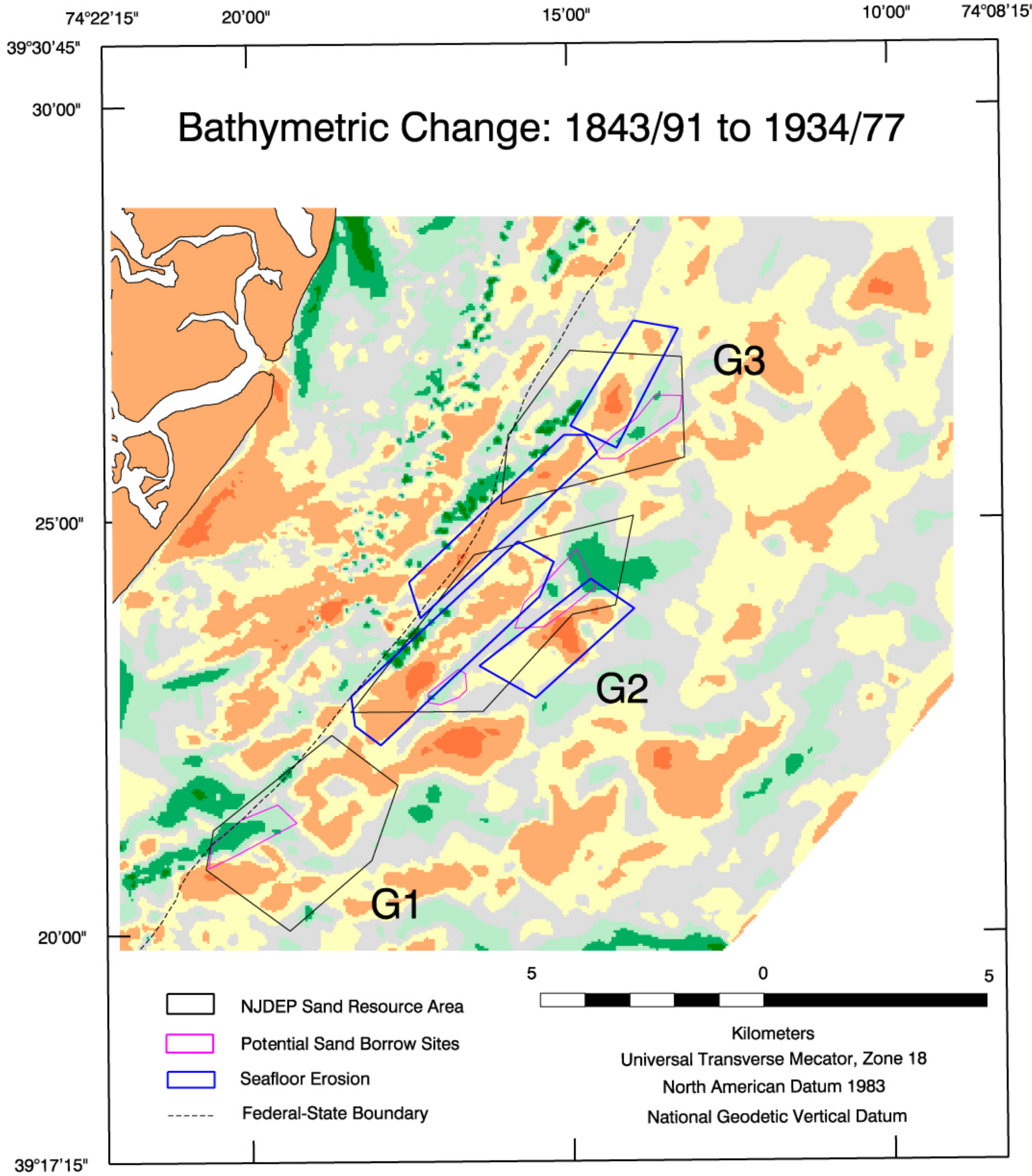

Figure 3-18. Potential borrow site locations relative to sand ridge erosion and deposition in Resource Areas G1, G2, and G3.

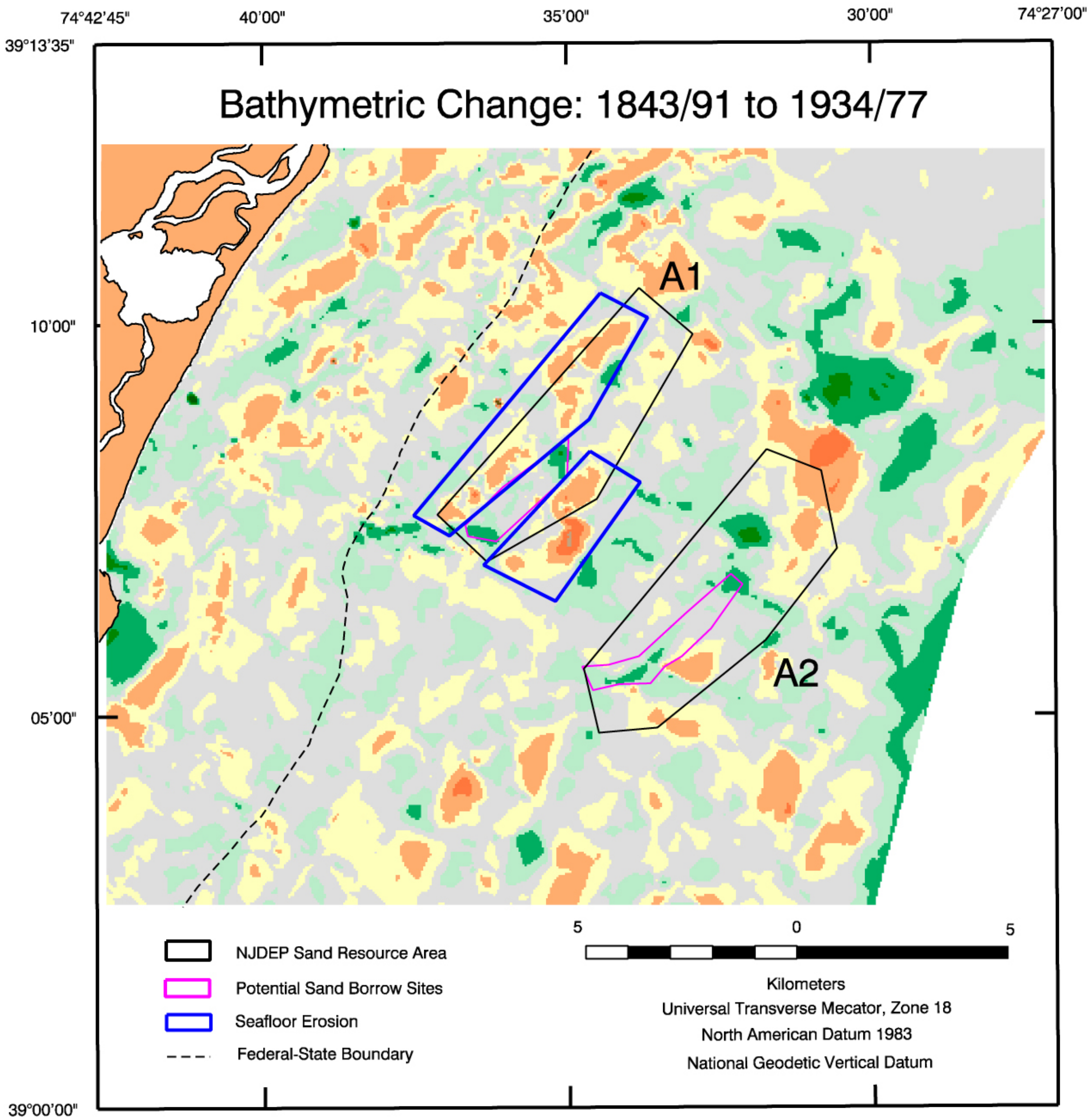

Figure 3-19. Potential borrow site locations relative to sand ridge erosion and deposition in Resource Areas A1 and A2.

The littoral zone extends seaward to about the 7-m (NGVD) depth contour, which represents the approximate depth of closure (based on calculations of d_l from Hallermeier [1981] using USACE Wave Information Study [WIS] data statistics). Along the southeastern coast of New Jersey, alternating zones of erosion and accretion, as determined from historical bathymetry comparisons, were evaluated with respect to the net sediment budget to determine net longshore sand transport rates. For the area south of Little Egg Inlet, net longshore transport rates were determined to be on the order of 70,000 m^3/yr. South of Great Egg Harbor Inlet, data become available again for quantifying net transport rates. As illustrated in Figure 3-17, the quantity of material deposited along the beaches south of Townsends and Hereford Inlets is significantly greater than deposition or erosion trends to the north. As such, net transport rates along the shoreline landward and south of Resource Areas A1 and A2 were determined to be on the order of 190,000 to 230,000 m^3/yr. These results are consistent with published estimates of net longshore sediment transport rates by the USACE (1996, 1997).

3.3 SUMMARY

Shoreline position and nearshore bathymetry change document four important trends relative to study objectives. First, the predominant direction of sediment transport throughout the study area is north to south. Southern Long Beach Island (north of Little Egg Inlet) and southern Island Beach (north of Barnegat Inlet) have migrated at a rate of about 14 m/yr to the south since 1839/42. The ebb-tidal shoals at all inlets in the study area are skewed to the south, and the channels are aligned in a northwest-southeast direction.

Second, the most dynamic features within the study area, in terms of nearshore sediment transport, are the ebb-tidal shoals associated with inlets along the southeastern barrier island chain. Areas of significant erosion and accretion are documented for the period 1843/91 to 1934/77, reflecting wave and current dynamics at entrances, the influence of engineering structures on morphologic change, and the contribution of littoral sand transport from the north to sediment bypassing and shoal migration.

Third, alternating bands of erosion and accretion on the continental shelf east of the Federal-State boundary illustrate relatively slow but steady reworking of the upper shelf surface as sand ridges migrate from north to south. The process by which this is occurring at Resource Areas G1, G2, and G3 suggests that a borrow site in this region would fill with sand transported from an adjacent site at a rate of about 62,000 to 125,000 m^3/yr. At Sand Resource Areas A1 and A2, the potential sand transport rate increases to 160,000 to 200,000 m^3/yr. This increase in potential transport rate reflects a more dynamic offshore environment seaward of the southern barrier island chain. Historical bathymetry change data were not available for quantifying sediment transport trends at Resource Areas C1, F1, and F2.

Finally, net longshore transport rates determined from seafloor changes in the littoral zone between Little Egg Inlet and the beach south of Hereford Inlet indicate an increasing transport rate to the south from about 70,000 m^3/yr south of Little Egg Inlet to 190,000 to 230,000 m^3/yr at Townsends and Hereford Inlets. Variations in transport rate are evident in the patterns of change recorded on Figure 3-17. It appears that areas of largest net transport exist just south of these entrances as a result of natural sediment bypassing from updrift to downdrift barrier beaches.